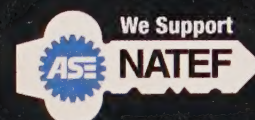
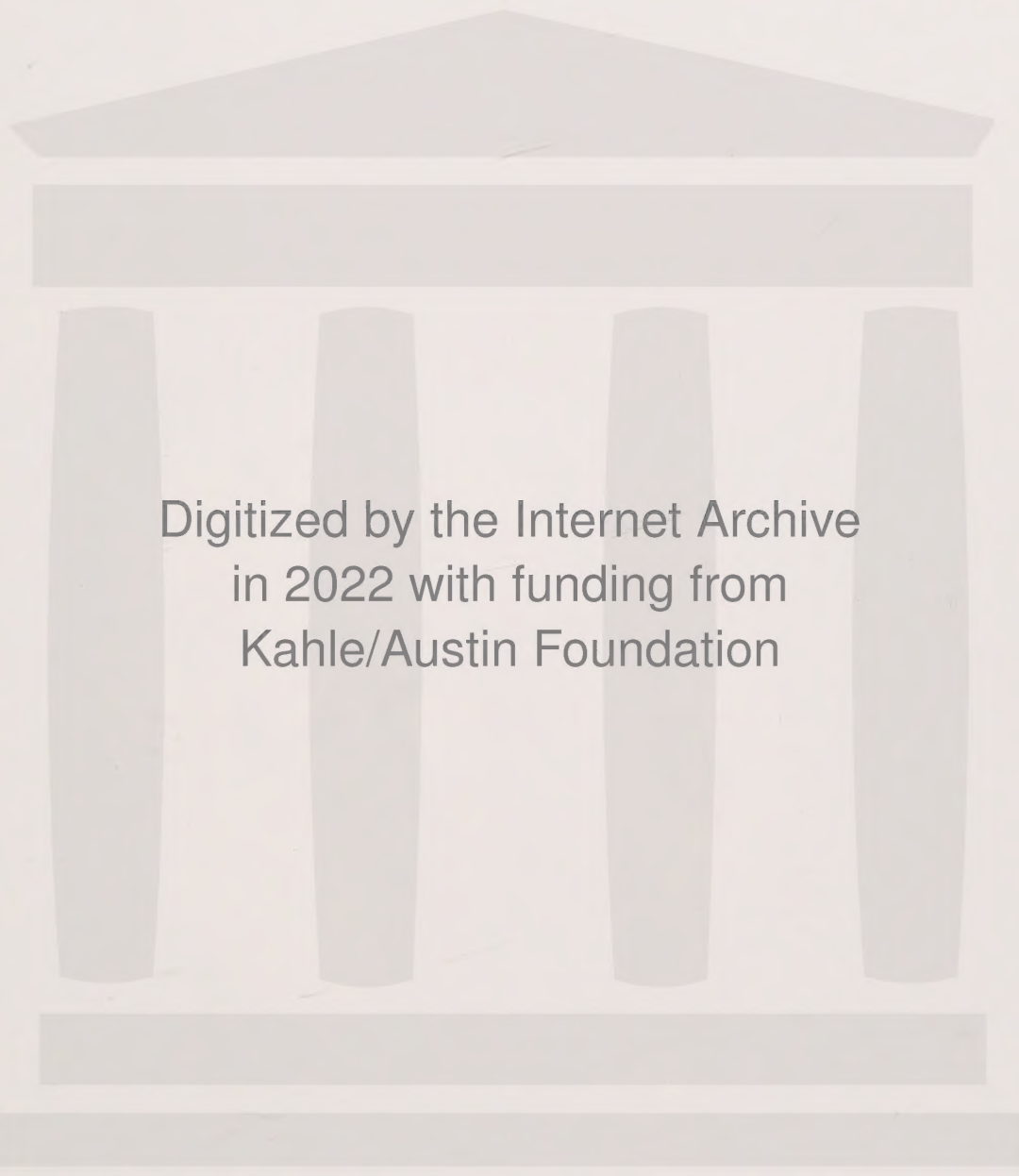


Manual Drive Trains and Axles

Third Edition

Chris Johanson and James E. Duffy





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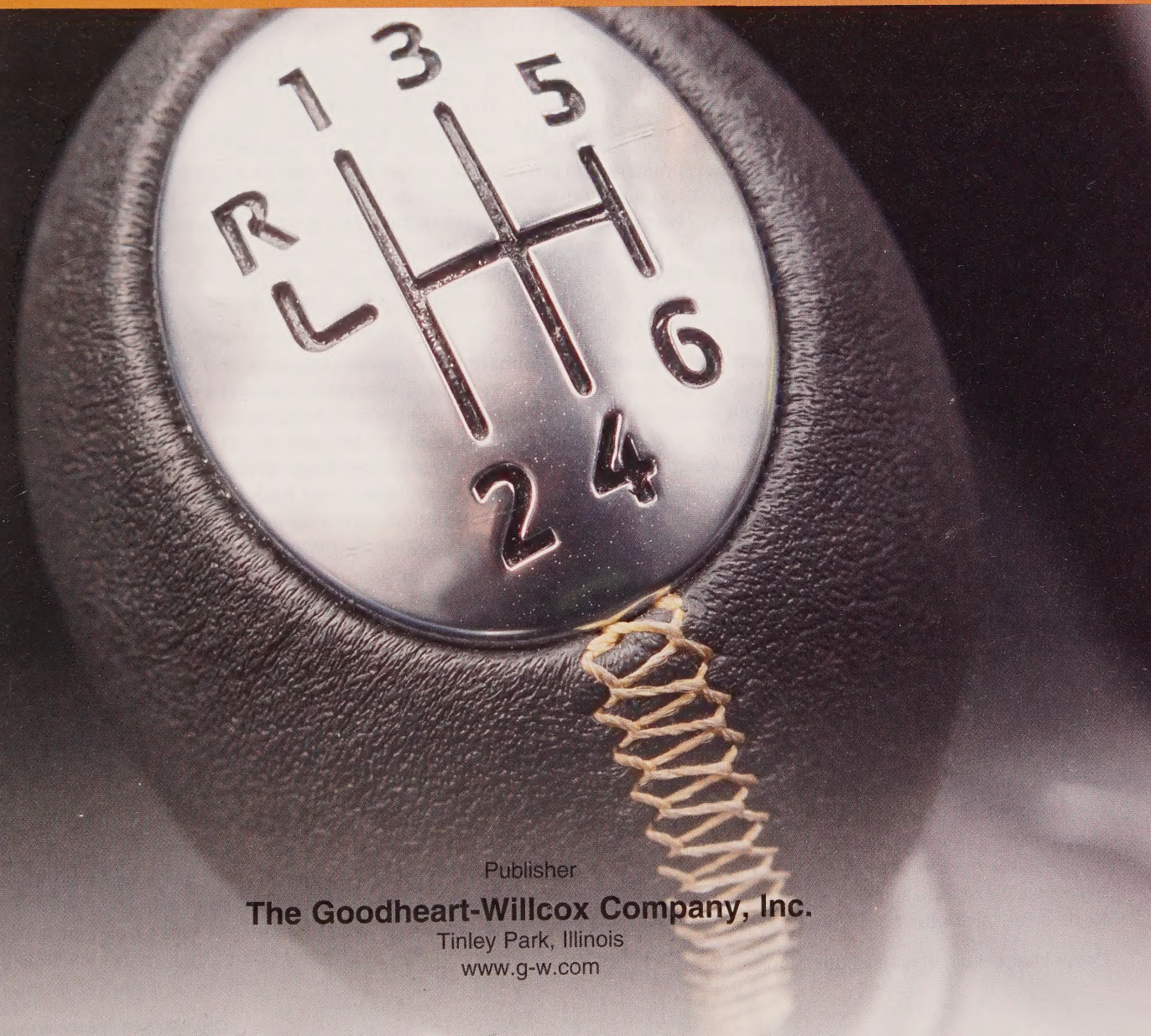
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Manual Drive Trains and Axles

Third Edition

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Automotive Writer



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Introduction

Some vehicle drive train parts have remained unchanged for many years. Most drive train systems, however, have undergone changes, and many new drive train parts have been introduced. Many manual transmissions now contain as many as six forward gears, compared to the three-speed units of years ago. Components that were rare in the past, such as transfer cases, limited-slip differentials, and two-piece drive shafts, are increasingly found on light trucks and SUVs. Transaxles and CV axles, once novelties, are now used on most automobiles. Some vehicles are equipped with completely new drive train systems, such as electronically controlled transfer cases and hydraulically locking differentials.

In the past, the drive train technician could learn by doing, that is, learn about parts and systems as he or she performed repairs. Today, this is no longer possible. Experimentation cannot be tolerated in today's competitive repair market. Both labor and parts are too expensive to be wasted on trial-and-error methods. Since many drive train parts are controlled by or send a signal to the on-board computer, the technician must have an understanding of basic electricity and electronics and must know how to use a scan tool to diagnose these drive train parts. Today's technician must also be aware of the special service tools required by many components and the procedures used to repair the more easily damaged drive train parts that are made of aluminum and magnesium.

Manual Drive Trains and Axles provides theory and service information for all modern drive train components. This includes information on the latest versions of clutches, manual transmissions and transaxles, solid and independent rear axle assemblies, drive shafts and drive axles, U-joints, CV joints, and center supports. Basic drive train components such as gears, bearings, and seals are identified and explained, along with the principles of hydraulic systems. The text also includes basic electricity and electronic principles, detailed explanations of the operation of electronically controlled components, and overall electronic control systems.

The textbook is arranged so that operating principles, system designs, and component parts are fully explained before diagnosis and repair procedures are discussed. Each chapter begins with a list of objectives that identify the focus of the chapter. The beginning of each chapter also contains a list of important technical terms. Look for these terms as you read through each chapter. They are presented in ***bold italic type*** when first used in the text and are defined when introduced. Figure references are presented in **bold type** for ease of identification. Notes provide supplemental information on the material presented in the text. Cautions are presented when the risk of property damage is possible. Warnings are presented when personal injury is possible, either during service or when the vehicle is operated after repairs. Each chapter closes with a Summary, Review Questions, and ASE-Type Questions.

In a few years, it will become difficult for the automotive technician to get a job if he or she is not ASE certified. The National Institute for Automotive Service Excellence, or ASE, was established almost 30 years ago to increase technician standards by, among other things, giving a series of standardized tests in various automotive areas. *Manual Drive Trains and Axles* is a valuable aid to those preparing for the ASE certification test A3, Manual Drive Trains and Axles. The content is correlated to the ASE/NATEF task list. ASE-type questions at the end of each chapter help prepare you for the kinds of questions asked on the ASE tests. In addition, Chapter 21 provides information on preparing for and taking the ASE tests.

A workbook correlated to *Manual Drive Trains and Axles* is also available. The workbook contains additional test questions, including more ASE-type questions. The chapters in the workbook are correlated to those in the textbook. The workbook also has drive train related jobs that develop your ability to perform hands-on service.

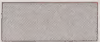
By choosing *Manual Drive Trains and Axles*, you have made a good start in preparing for a future in the field of automotive service and repair.

Chris Johanson

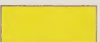
How to Use the Color Key

Colors are used throughout *Manual Drive Trains and Axles* to help illustrate different transmission, transaxle, and differential components. Color is also used to help clarify power flow. The following key shows what each color represents.

Transmission, Transaxle, and Differential Components

Gears, shafts, and axles	
Clutch and related components, shift forks, shift rails, synchronizers, joints, and bearings	
Electronic control components (sensors solenoids, etc.)	
Case, housings, and oil pans	

General Illustrations

Primary component or feature	
Secondary component or feature	
General components	
General components	

Power Flow

Drive gear	
Driven gear	

The direction of power flow and the direction of force are indicated by red arrows.





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Chapter 1

Introduction to Drive Trains

After studying this chapter, you will be able to:

- ☐ List the basic functions of a drive train.
- ☐ Describe the different types of drive trains.
- ☐ List the basic parts of a rear-wheel drive system.
- ☐ List the basic parts of a front-wheel drive system.
- ☐ List the basic parts of a four-wheel drive system.
- ☐ Summarize the fundamental purposes of major drive train components.
- ☐ Explain the difference between a transmission and a transaxle.

Technical Terms

Drive train	Ring and pinion	All-wheel drive system
Power flow	Rear axle ratio	Manual transmission
Transaxle	Front-engine, front-wheel drive system	Drive shaft
Front-engine, rear-wheel drive system	Transverse mounting	Universal joint
Conventional mounting	Constant-velocity universal joints	Slip yoke
Clutch	Mid-engine, rear-wheel drive system	Rear axle housing
Transmission	Rear-engine, rear-wheel drive system	Rear drive axle
Drive shaft assembly	Four-wheel drive system	Front drive axle
Rear axle assembly	Transfer case	Rzeppa joint
Final drive		Manual transaxle
Differential assembly		

Introduction

This chapter presents the various vehicle drive trains and major drive train parts. It also explains how the drive train relates to engine location and to body and chassis design.

Before you learn the detailed principles and service of drive train components, you should know what components are parts of the drive train. You have heard of gears, clutches, bearings, couplings, and drive shafts. All of these parts relate to a vehicle drive train. This chapter will help you more easily see the place of such parts in the drive train's operation.

The Drive Train

Internal combustion engines convert the chemical energy in fuel into rotation at the crankshaft. They do this by causing the fuel to burn in the engine cylinders, creating pressure that pushes the piston downward in the cylinder. The arrangement of the pistons, connecting rods, and crankshaft causes the crankshaft to turn. While the internal combustion engine is a versatile power source, it cannot transmit power directly to the drive wheels. Engines are most efficient only over a narrow rpm range, cannot be stopped whenever the vehicle is not moving, and have no way of reversing direction. A method of converting engine power into usable power at the drive wheels is necessary. This is the job of the drive train.

The **drive train** is what transmits the engine power to the road. It is the part of the vehicle that connects the engine to the drive wheels. The drive train modifies engine power output to match vehicle needs. For example, the drive train provides a way to multiply torque (turning force) from the engine when the vehicle is starting off. It also provides a way to reduce engine rpm at higher vehicle speeds to improve gas mileage. In addition, the drive train provides a way to select the direction of vehicle travel, or select whether the vehicle moves forward or backs up.

The drive train consists of various mechanical and, sometimes, hydraulic and electronic components that form a path for engine power. This path is referred to as the **power flow**. Drive train components are usually arranged in a way that transmits power most efficiently. The arrangement may include, for example, a clutch, transmission, drive shaft assembly, differential assembly, and drive axles. Two basic ways the parts can be arranged are shown in **Figure 1-1**. Note that the parts of the drive train are shaded in the illustration.

Figure 1-1A shows a system where the engine is in front and power is transmitted to the rear drive axles. This is a typical front-engine, rear-wheel drive system. For many years, this drive train design was almost the only kind used in domestic and imported vehicles.

Figure 1-1B shows a system in which the engine is placed directly over the drive axles. This system features a **transaxle**—a combination of a transmission and a

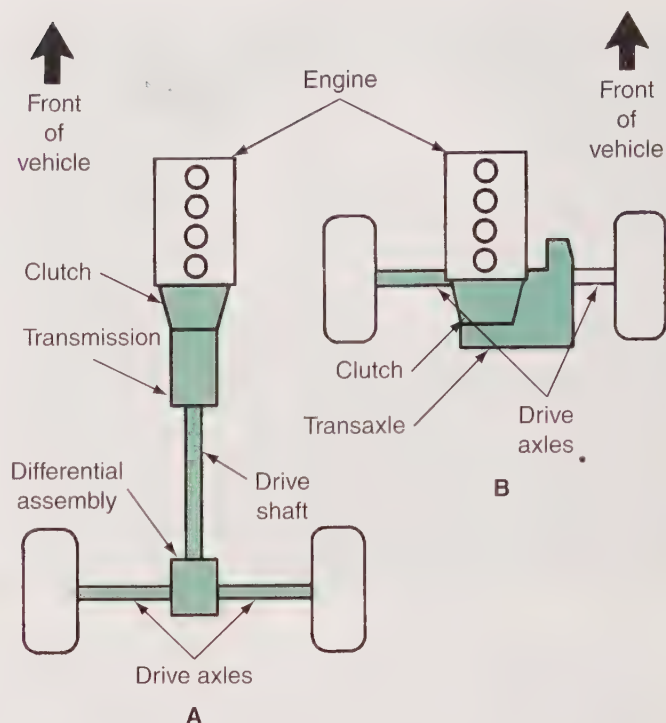


Figure 1-1. Two basic kinds of drive trains. A—This arrangement is found in front-engine, rear-wheel drive vehicles. B—This arrangement is found in some front-wheel drive and some rear-wheel drive vehicles.

differential assembly. The design can be used to drive either front or rear axles. Transaxles are common on front-engine vehicles. Mid- and rear-engine designs, which use transaxles to drive rear wheels, are less common. Porsche uses this arrangement on its 911 models.

Front-Engine, Rear-Wheel Drive

Figure 1-2 is a further breakdown of a **front-engine, rear-wheel drive system**. The placement of the engine in the vehicle is called a **conventional**, or **longitudinal, mounting**. In this arrangement, the engine is positioned so the water pump and drive belts are at the front of the vehicle. The crankshaft centerline runs parallel to the centerline of the vehicle.

The engine feeds power into a **clutch** or a **torque converter**. The clutch is used on vehicles with manual transmissions. The torque converter is used on vehicles with automatic transmissions. (Though shown separately in **Figure 1-2**, the torque converter is considered an integral part of the automatic transmission, while the clutch on a manual transmission vehicle is a separate unit.) Both the clutch and torque converter serve as a way to connect or disconnect the flow of power from the engine to the drive wheels. The clutch transmits the power by means of a friction coupling, and the torque converter transmits power by means of a fluid coupling.

From the clutch, engine power goes directly into the **transmission**. The transmission multiplies engine torque or reduces engine rpm to match varying forward operating

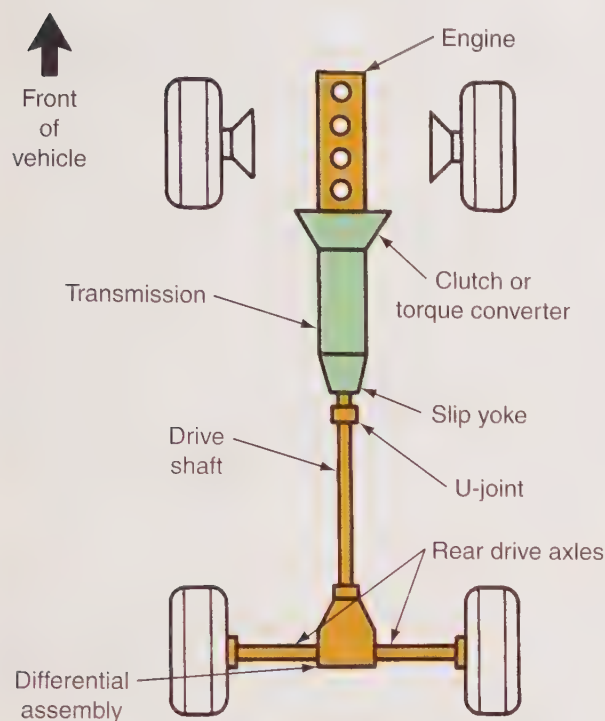


Figure 1-2. Power train layout of a typical front-engine, rear-wheel drive vehicle. Notice that engine, clutch, transmission, drive shaft, and differential assembly are placed in a straight line. The ring and pinion cause the power flow to take a 90° turn inside the differential assembly to drive the rear wheels.

conditions. It also provides a way to move a vehicle in the reverse direction. The manual transmission uses gears of different sizes to obtain different gear ratios and achieve these results. The driver selects the proper gear.

If the vehicle has an automatic transmission, engine power exits the torque converter and enters the automatic transmission. The automatic transmission drives different combinations of planetary gears to obtain different forward gear ratios, as well as reverse. A hydraulic control system on the automatic transmission selects the proper gear. On the newest transmissions, the on-board computer controls the hydraulic system.

From the transmission, the power flow goes to the **drive shaft assembly**, or **driveline**. This assembly consists of a drive shaft, front and rear universal joints, and a front slip yoke. The drive shaft assembly is designed to provide a smooth delivery of power to the rear axle assembly, while allowing the rear axle to move up and down to compensate for road conditions.

The **rear axle assembly**, sometimes called the **rear end**, sends power from the driveline to the drive wheels. It is made up of a differential assembly and drive axles, which are encased in a housing that is considered part of the rear axle assembly.

Note that the rear axle assembly is sometimes referred to as the **final drive**. This term, which also applies to front-wheel drive vehicles, refers to the final stage of a drive train. It includes the combination of the differential and drive axles.

The **differential assembly** houses a number of gears, **Figure 1-3**. Two of these gears, the drive pinion gear and the ring gear, redirect the power flow 90° to drive the rear wheels. The pinion gear and the ring gear are commonly referred to as a **ring and pinion**.

The shaft of the drive pinion gear is connected to the driveline. The gear itself meshes with the ring gear. The rotational axes of the two gears are offset and form a 90° angle, making them hypoid gears. The number of teeth in the ring gear compared to the number of teeth in the drive pinion gear sets the **rear axle ratio**. Higher rear axle ratios provide better acceleration and pulling power. Lower ratios provide better fuel economy.

In addition to redirecting the power flow, the differential assembly allows the drive wheels to revolve at different speeds during vehicle turns. Two differential spider gears and two differential side gears serve this function. (This will be explained later in greater detail.) The drive axles are attached to the differential side gears. As these gears rotate, power is transmitted from the rear axle assembly to the rear wheels.

Front-Engine, Front-Wheel Drive

Most **front-engine, front-wheel drive systems** appear as in **Figure 1-4**. Note the engine is installed at a 90° angle to the vehicle's centerline. This sideways layout is usually referred to as **transverse mounting**. Since there is no need to change the angle of power, a hypoid ring and pinion are *not* needed. This is a key difference between drive trains following longitudinally mounted, or longitudinal, engines and those following transversely mounted, or transverse, engines.

In a transversely mounted system, power flows from the engine to the transaxle, flowing first through a clutch in the case of a manual transaxle. The transmission, which is part of the transaxle, is located to one side of the engine. It performs the same function as on a rear-wheel drive system. The transaxle transmission sends the power flow directly into the differential assembly, which is also a part of the transaxle.

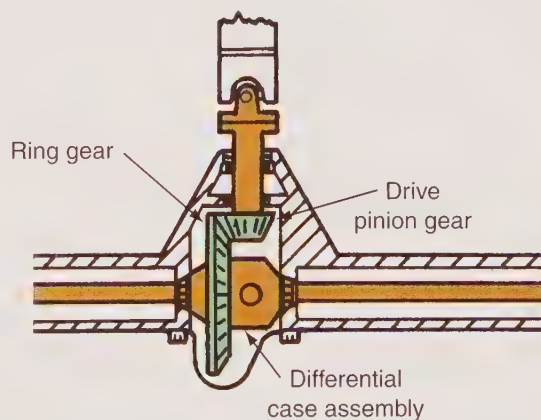


Figure 1-3. The drive pinion gear and the ring gear inside of the differential assembly redirect the power flow 90° to deliver power to the rear wheels.

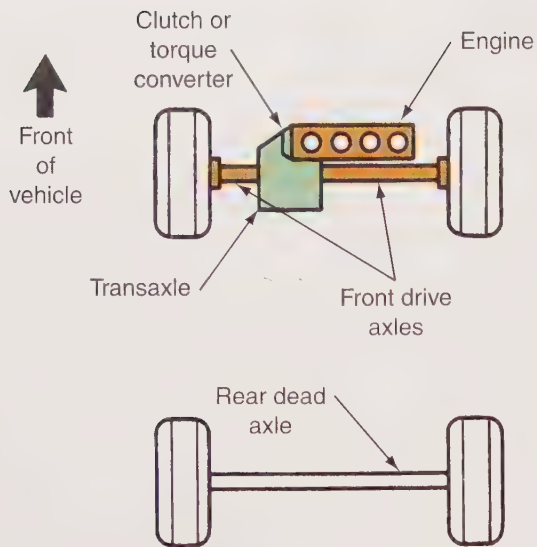


Figure 1-4. A front-wheel drive vehicle with a transverse mounted engine uses a transaxle to transmit power from the engine to the wheels. The axes of all rotating parts, from engine to wheels, have the same orientation. This makes it unnecessary for the power flow to make a turn at the differential assembly. The design makes a hypoid ring and pinion unnecessary in the differential assembly.

Power is split at the transaxle differential and travels to each wheel through separate axles. These axles are *not* enclosed. The axles use flexible joints called **constant-velocity universal joints**, or **CV joints**. CV joints are used because they provide a constant flow of power through angles between drive and driven shafts. The transaxle differential allows each wheel to turn at different speeds during turns.

In some front-wheel drive vehicles, the engine is installed with a longitudinal mounting. See **Figure 1-5**. The transaxle is similar to that used with a transverse engine;

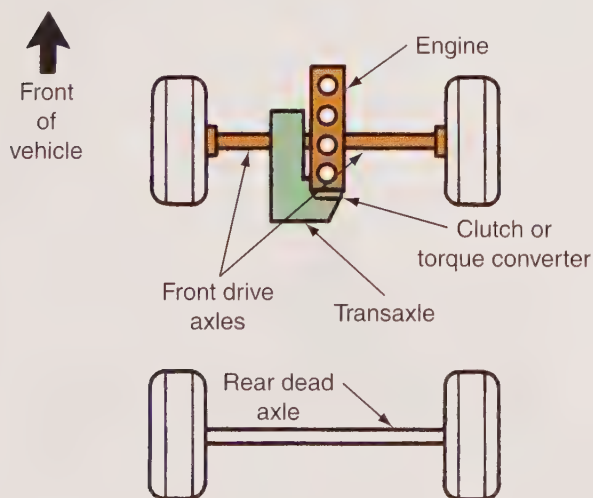


Figure 1-5. This is a front-wheel drive system, but the engine is longitudinally mounted, as it is on a rear-wheel drive vehicle. Although this system uses a transaxle, it has a hypoid ring and pinion.

however, it must include a ring and pinion to allow the engine power to make a 90° turn. The other drive train components operate in the same manner as those on a vehicle with a transverse engine.

Mid-Engine, Rear-Wheel Drive

The **mid-engine, rear-wheel drive system** is illustrated in **Figure 1-6**. Power flows from the engine (through the clutch in manual transaxles) into the transaxle transmission. From here, power flows directly into the differential section of the transaxle and then to the drive axles. This design resembles a conventional front-engine system in that the engine is mounted longitudinally. This rear-wheel drive system differs, however, in that it has a transaxle.

Rear-Engine, Rear-Wheel Drive

Figure 1-7 shows a **rear-engine, rear-wheel drive system**. The engine is transverse mounted. The drive train operates in the same manner as that in a transverse front-engine, front-wheel drive vehicle.

On some rear-wheel drive vehicles, the engine is mounted behind the drive train components, **Figure 1-8**. The transaxle differential section and rear drive axles are mounted in front of the engine. The transmission section of the transaxle sits in front of the transaxle differential section and rear drive axles. Power flows from the transmission section to the differential section through a hollow shaft. Power flows to the transmission through a shaft that revolves inside the transmission output shaft. See **Figure 1-9**. Other drive train components operate as they do in the conventional rear-wheel drive system.

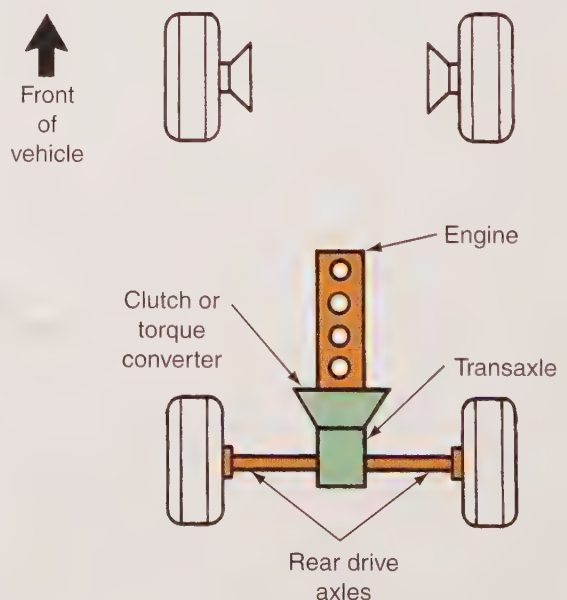


Figure 1-6. A mid-engine, rear-wheel drive system uses a transaxle. The power flow must be diverted 90°.

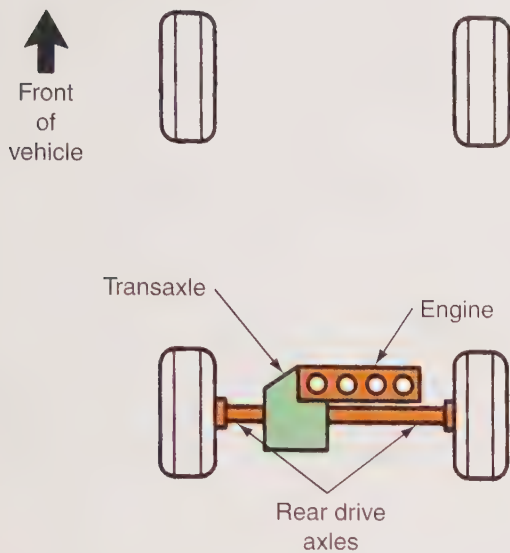


Figure 1-7. The power flow of the transverse mounted rear-engine, rear-wheel drive system resembles that of a transverse mounted front-engine, front-wheel drive system. Power flow is from the engine to the transaxle (through the clutch in manual transaxles), to the rear drive axles, and to the rear wheels.

Four-Wheel Drive

The **four-wheel drive system**, **Figure 1-10**, somewhat resembles a conventional rear-wheel drive system. In addition, the four-wheel drive system has a front axle assembly, similar to the rear axle assembly. It also has a separate gearbox, called a **transfer case**. Through the transfer case, power can be transmitted to front and rear axle assemblies through an arrangement of gears. The gear ratio from

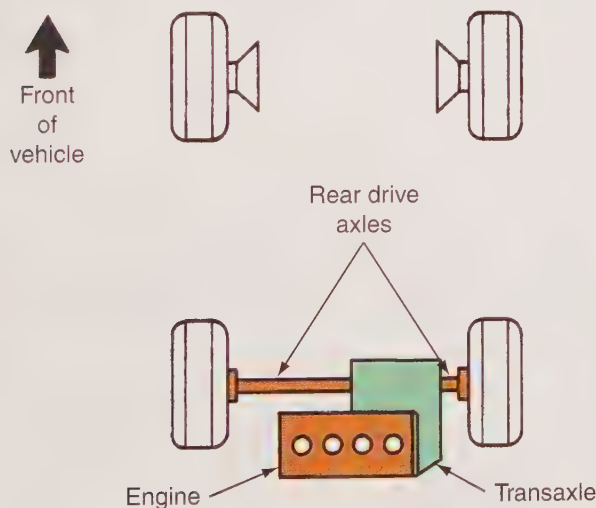


Figure 1-8. Rear-engine, rear-wheel drive system. The engine is mounted at the extreme rear of the vehicle. Power flow is forward to the transaxle. The transaxle differential is often mounted between the engine and transmission section of the transaxle. To transmit power, the input shaft to the transmission is placed inside a hollow output shaft. Power flows through the input shaft into the transmission. The hollow output shaft transmits power into the transaxle differential.

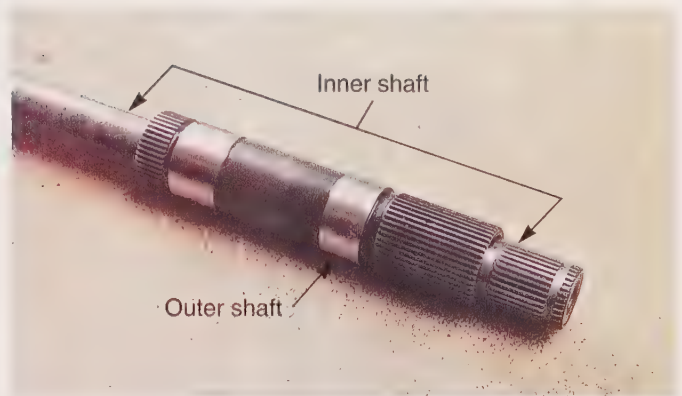


Figure 1-9. Some shafts are hollow to permit other shafts to rotate inside them. Hollow shafts are commonly used on transaxes.

engine to rear wheels is always equal to the gear ratio from engine to front wheels; therefore, front and rear wheels revolve at the same rate.

In the original four-wheel drive system, two- and four-wheel drive is selected manually; the vehicle driver decides which drive to use. On some newer vehicles, an on-board computer makes the decisions, and the driver only partially controls the system. The **all-wheel drive system**, **Figure 1-11**, a type of four-wheel drive system, is

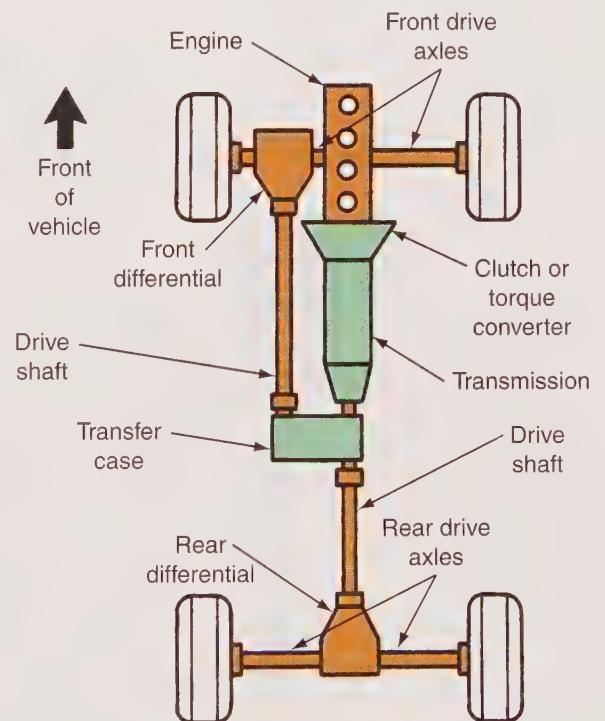


Figure 1-10. In the four-wheel drive system, power may be delivered to both front and rear wheels. The system contains a front drive shaft and final drive, which resemble the rear drive components. The heart of the four-wheel drive system is the transfer case. The driver selects two-wheel or four-wheel drive. In four-wheel drive, the transfer case divides power between the front and rear drive shafts. In two-wheel drive, it sends power only to the rear.

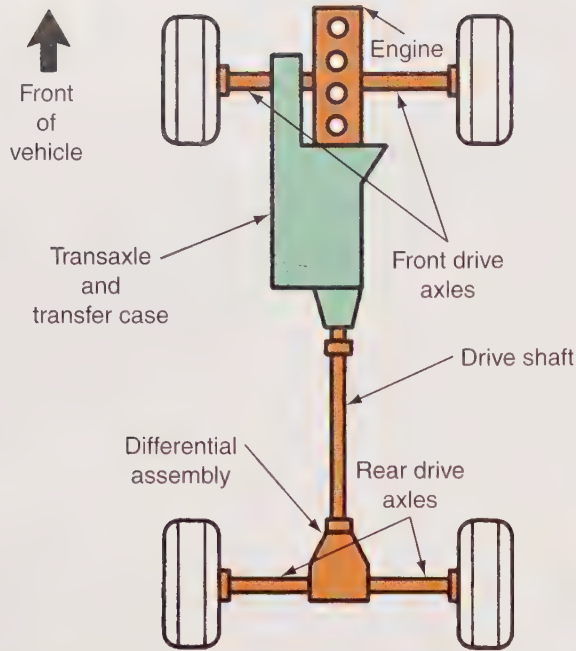


Figure 1-11. The transfer case of an all-wheel drive vehicle automatically splits the power flow according to traction requirements. These transfer cases contain an internal fluid coupling, which is a device that transfers motion by using a fluid. It allows the front and rear wheels to turn at different speeds.

in four-wheel drive at all times. A special internal clutch in the transfer case can divert more or less power to the front wheels depending on road conditions.

Drive Train Parts

Certain drive train parts are common to all types of drive train layouts. Differences often occur only in the placement of these components on the various vehicles. Four-wheel drive systems have some additional parts. Thus far, all of these parts have been mentioned. This section takes a closer look at all of these components.

Clutches

Clutches are always used on vehicles with manual transmissions and transaxles. The clutch is located directly behind the engine. It is almost always mounted on the engine flywheel. The clutch connects and disconnects the engine from the other parts of the drive train, **Figure 1-12.**

Clutches use friction to transmit rotary motion. This is called a friction coupling. The presence of friction between two parts in contact with each other will cause, to

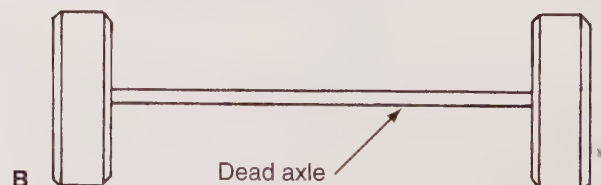
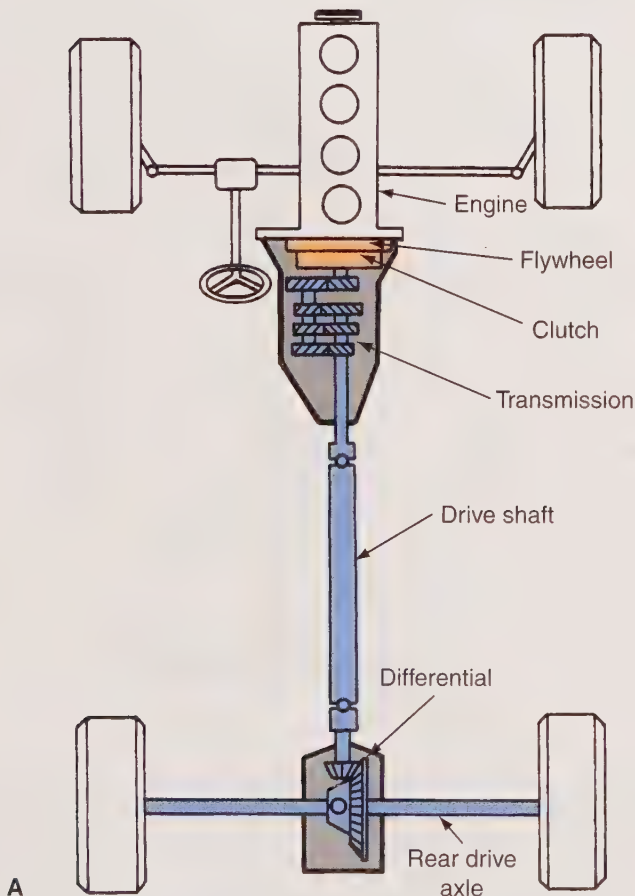
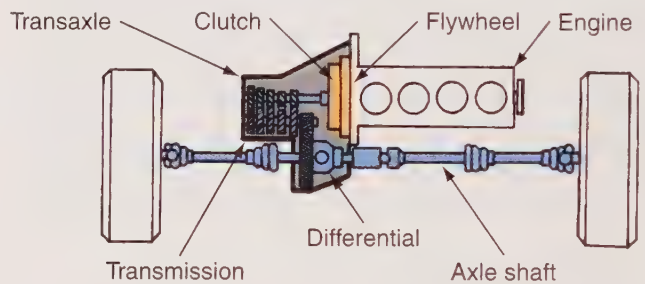


Figure 1-12. Compare the front- and rear-wheel drive systems shown here. The clutch is always mounted directly behind the engine, on the flywheel. Automatic transmissions and automatic transaxles will have a torque converter mounted directly behind the engine, instead of a clutch.

some degree, resistance of motion between them. At some point, relative motion between the two parts is altogether prevented.

A simple clutch is shown in **Figure 1-13**. In normal position, **Figure 1-13A**, the two surfaces are pressed together. The clutch is engaged. Rotary motion is transmitted through the disc surfaces. The clutch is disengaged, **Figure 1-13B**, by depressing a foot pedal connected to a clutch release mechanism. When the clutch pedal is released, the clutch re-engages.



Note: A torque converter is used when the vehicle has an automatic transmission or transaxle. Automatic transmissions are not covered in this book.

Transmissions

The purpose of the transmission is to match engine power and speed to vehicle conditions. The transmission must provide a high gear ratio for takeoff and acceleration and a low gear ratio during highway operation. A transmission will have several gear ratios to allow for efficient operation under various conditions. Manual transmissions are located behind the clutch. The transmission output on a front-engine, rear-wheel drive vehicle goes to the drive shaft. See **Figure 1-14**. On front-engine, front-wheel drive vehicles, a drive shaft is *not* needed.

In the **manual**, or **standard**, transmission, **Figure 1-15**, the vehicle operator makes the gear selection decisions. Transmission gears and gear synchronizers are moved in and out of engagement by shift forks. The gears are meshed in different combinations. The driver selects different gear ratios by choosing the combinations needed. The driver

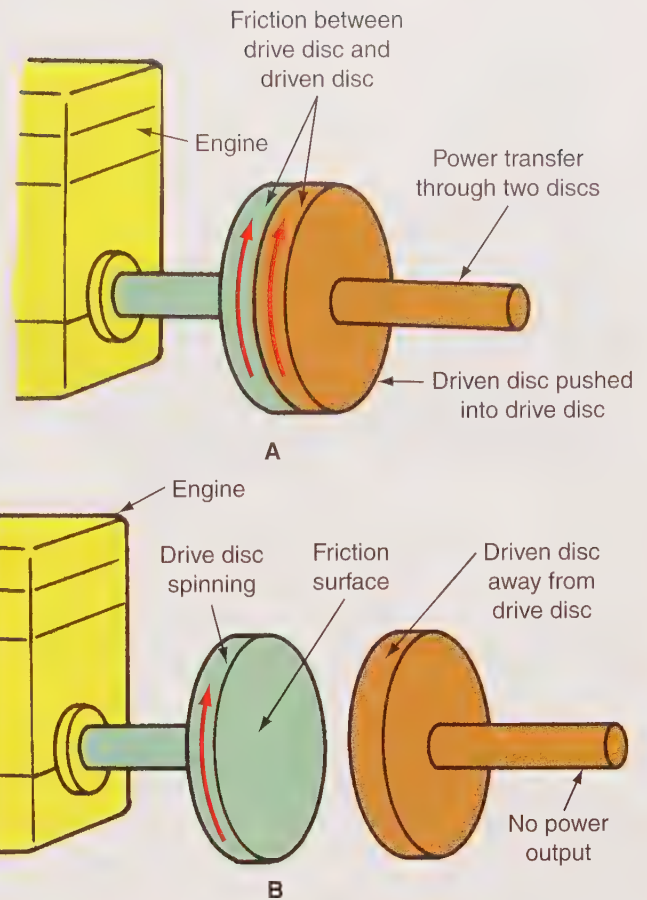


Figure 1-13. Operation of a simple clutch. A—When clutch discs are pressed together, a solid contact is formed. Rotation of the first disc causes the rotation of the second disc. B—One disc is spinning. There is no contact between the discs, and rotation is not transmitted.

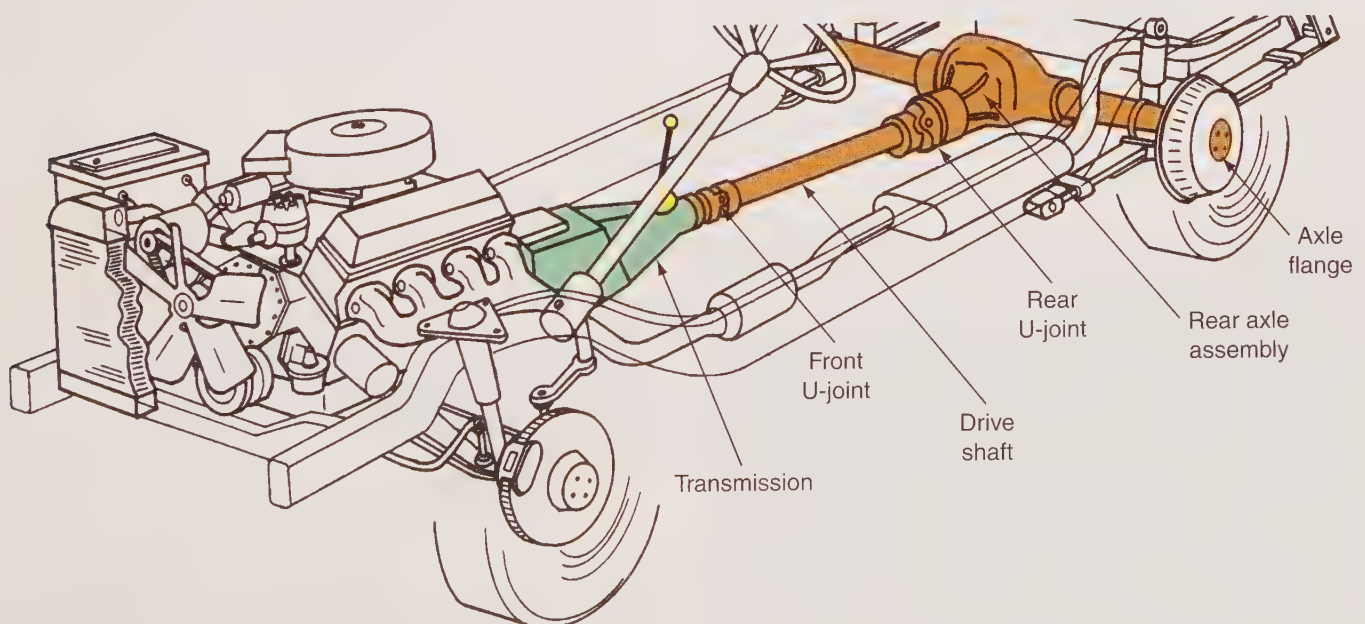


Figure 1-14. This shows how the drive train components of a rear-wheel drive vehicle relate to the other chassis components. The transmission is always directly behind the engine, and the drive shaft connects the transmission to the rear axle assembly.

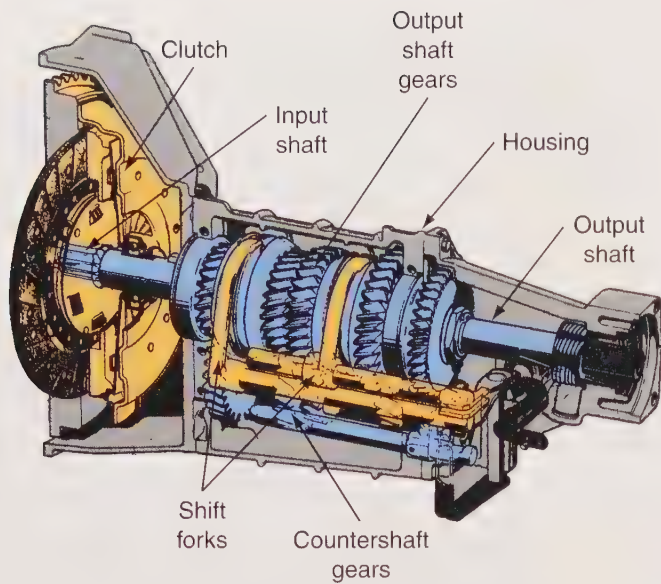


Figure 1-15. The rear-wheel drive system clutch and manual transmission shown here are typical. The components are found on all makes of manual transmissions. (Peugeot)

must also operate the clutch pedal to disengage the clutch when changing gears. Manual transmissions require more skill to operate than automatic transmissions, but they allow more control over vehicle operation. They are usually easier and cheaper to repair. Some late model manual transmissions are electrically connected to the on-board computer. The on-board computer receives speed and gear position inputs from the transmission. A few vehicle computers can partially control transfer case operation.

Dual Clutch Transmission

Another type of manual transmission is known as the dual clutch transmission, or DCT. The DCT can be thought of as two transmissions, each with its own clutch, in one housing, **Figure 1-16**. In a five-speed DCT, one transmission contains the odd-numbered gears (first, third, and

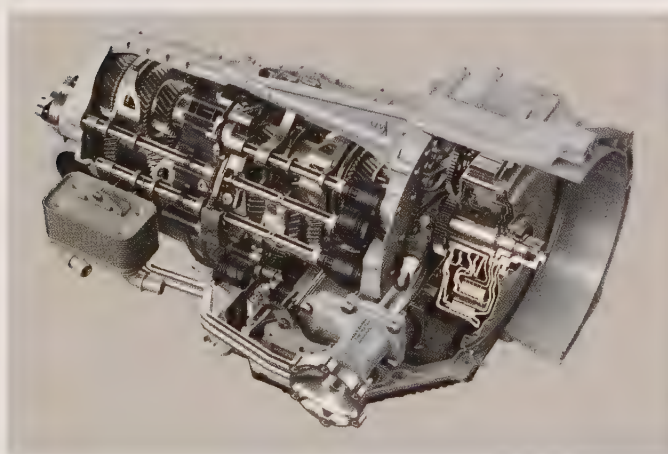


Figure 1-16. A dual clutch transmission.

fifth) and the other transmission contains the even-numbered gears (second, fourth). Hollow shafts allow each transmission to transfer power without interfering with the other transmission. To reduce friction, the clutches may be wet clutches, or clutches that operate in oil-filled chambers. DCT vehicles have no clutch pedal, so shifts are made by a console shift lever or paddles mounted on the steering wheel.

Operation depends on alternately applying and releasing the clutches, and engaging gears before the clutches are applied. For instance, when the vehicle is accelerating in first, power flows through the clutch and first gear of the odd-gear transmission. As power travels through the odd-gear transmission, second gear of the even-gear transmission is engaged but is not yet delivering power. To shift to second, the odd-gear transmission clutch disengages and the even-gear transmission clutch engages. Power then flows through the clutch and second gear of the even-gear transmission. Meanwhile, third gear of the odd-gear transmission is engaged for the next shift. An electronic module precisely controls the gear selection and clutch application sequence. This results in fast, smooth shifts, with no gear clash or interruption in power flow.

A dual clutch transmission is almost as efficient as a conventional manual transmission. Some power, however, is lost to the oil in the wet clutch and hydraulic gear selection system.

Drive Shaft Assemblies

All front-engine, rear-wheel drive vehicles have a drive shaft. The **drive shaft**, or **propeller shaft**, is the means of transmitting power from the transmission to the rear axle assembly. It usually consists of a steel tube with a welded or press-fit yoke at each end. See **Figure 1-17**. The yokes join **universal joints**, often called **U-joints**, at each end of the shaft. U-joints allow for changes in driveline angles when the rear axle is moving up or down over road surface

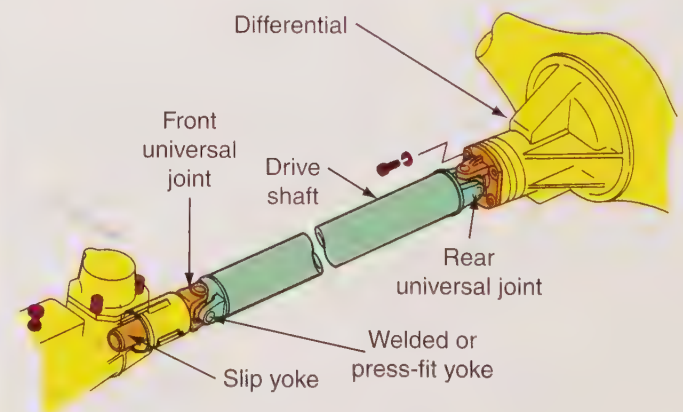


Figure 1-17. A typical rear-wheel drive system drive shaft. The drive shaft used on the front of a four-wheel drive system is similar. Most modern drive shafts have two universal joints. However, you may encounter drive shafts with one or three universal joints. (Mazda)

irregularities. Some drive shafts are two-piece units with three universal joints.

The front of the drive shaft connects through the U-joint to the **slip yoke**, which slides back-and-forth within the transmission. It allows the drive shaft length to change with rear axle movement. A slip yoke may also be mounted at the rear of the front drive shaft in four-wheel drive vehicles.

Rear Axle Assemblies

The job of the rear axle assembly, **Figure 1-18**, is to transmit power from the drive shaft to the rear wheels. The **rear axle housing** contains the differential assembly, drive axles, and related parts. The housing forms a rigid support for the rear of the vehicle. Heavy gear oil contained in the housing lubricates the moving parts.

The drive pinion gear is attached to the rear universal joint by the differential pinion yoke. The pinion gear is in constant mesh with the ring gear. The pinion, turned by the drive shaft assembly, turns the ring gear. By design, the rpm at the ring and pinion output is reduced from driveline (input) rpm. In this way, the ring and pinion increases engine power. It also changes the power flow 90° so that it can drive the rear wheels. The ring gear has quite a few more teeth than the pinion. Therefore, the pinion must make more revolutions (usually between 2.5 and 4) to turn the ring gear one revolution. Note in **Figure 1-19** that the ring and pinion gears are mounted on large bearings. These bearings must be strong to handle the thrust forces created during the transmission of power from pinion to ring.

The rear axle assembly also contains a differential case. The case is bolted to the ring gear. The power flow enters the case and passes through a set of small gears before going to the drive axles. The set of gears contains two differential spider gears and two differential side gears. All four gears are meshed together.

The four differential case gears are locked together and rotate as a unit when the vehicle is moving in a straight line. This causes the drive axles to revolve at the same speed. A shaft that connects to the differential case drives the gears. The shaft extends through the two spider gears and rotates with the case. The four gears do *not* rotate among themselves when the vehicle is moving straight ahead.

When the vehicle is making a turn, however, the gears move in relation to each other, and the axles can turn at different speeds. This compensates for the difference in turning radius of the inner and outer wheels. The inner wheel, with the smaller turning radius, will turn at a slower speed than the outer wheel. This will cause the drive axle of the inner wheel and the related side gear to turn at a slower speed. The three remaining gears, as a unit, will “walk around” the slower-turning side gear and the faster-turning wheel will rotate at its own speed.

Sometimes the differential assembly operates when it is not desired, such as when one wheel is stuck on ice or in snow. When this happens, the wheel without traction spins. The wheel on firm ground stands still as power flow takes the easiest path—that of the spinning wheel. The three differential gears merely walk around the side gear of the wheel with traction, and the vehicle cannot move. To overcome this problem, some differential assemblies are equipped with an internal clutch mechanism. This clutch sends power to the wheel with the most traction or to both wheels, eliminating wheel spinning and allowing the vehicle to move.

The **rear drive axles** transmit power from the differential assembly to the rear wheels. Typical axles are straight and have ridges, or splines, at one end. The splined ends are attached to the differential gears, which drive the axles. The outer ends of the axles are flanged. The flanges provide the mounting surface for the wheel rims. The axle outer ends are supported by bearings. Some axles use greased

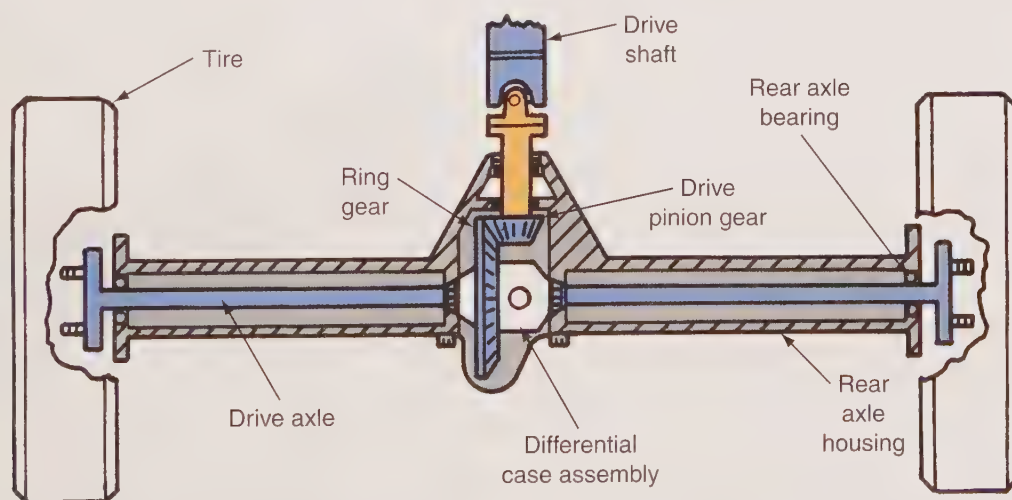


Figure 1-18. A typical rear axle assembly. The drive pinion gear and ring gear cause the power flow to make a 90° turn. The difference in the number of teeth between the ring and pinion determines the rear axle ratio. The ring gear is usually bolted to the differential case. The differential case assembly contains a set of four gears, arranged in a way that permits the rear wheels to turn at different speeds. The axles connect the differential assembly to the rear wheels. The entire rear axle assembly is contained in a sealed housing.

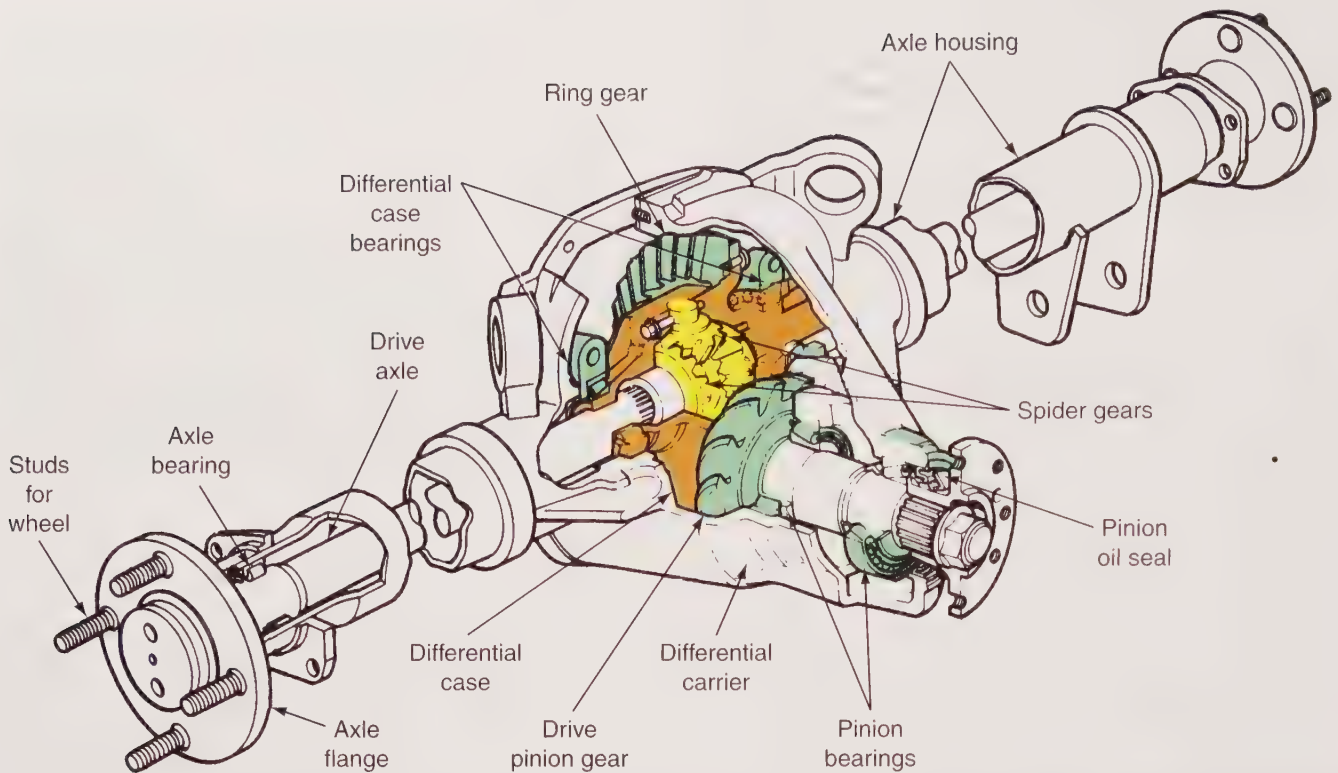


Figure 1-19. A detailed view of a rear axle assembly. Notice that the rear axle parts are supported by large bearings. These bearings are needed to handle the high weight and thrust forces placed on the rear axle assembly during vehicle operation. All parts of the rear axle assembly are under heavy stress. They are lubricated with heavy oil contained in the axle housing. (Ford)

and sealed axle bearings, while others lubricate the bearings with differential lubricant. A detailed picture of a rear drive axle is shown in **Figure 1-20**.

Transaxles

A transaxle is a combination of a transmission and a differential assembly. The transmission and differential are usually contained in a single case. While the fundamentals of the transaxle are similar to the fundamentals of the trans-axle in a rear-wheel drive vehicle, the component layout is different.

Figure 1-21 shows the placement of the transaxle on a typical front-wheel drive vehicle. Power flows from the engine into the clutch, the transaxle, and then to the drive axles. If the engine is placed transversely, there is no need to divert the angle of power flow, and a conventional hypoid ring and pinion is *not* needed.

A front-wheel drive system has two drive axles. **Front drive axles** are smaller than those used on rear-wheel drive vehicles, and they are usually solid. Most front drive axles use a kind of constant-velocity U-joint called a **Rzeppa** (pronounced ri-ze'-pa) **joint**. This joint is flexible and is, therefore, well suited to a front-wheel drive system. Some longer front axles have a second joint near the transaxle.

Figure 1-22 is a **manual transaxle**. Note that the manual transaxle gears resemble those of the manual transmission shown in **Figure 1-17**. These gears are operated by shift forks similar to those in the rear-wheel drive

transmission. Different combinations of gears are selected to obtain the desired gear ratios.

Four-Wheel Drive Components

The four-wheel drive system resembles a conventional rear-wheel drive system, with the addition of some extra

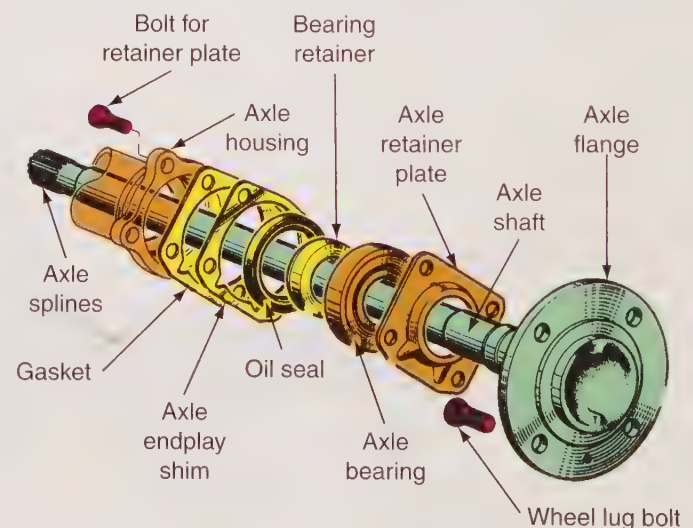


Figure 1-20. Another place where heavy bearings are needed is at the ends of the axle shafts. These bearings support the axle at the wheel. Some axle bearings are splash lubricated by the differential oil. Other bearings are permanently packed with grease and are isolated from the differential oil. (Toyota)

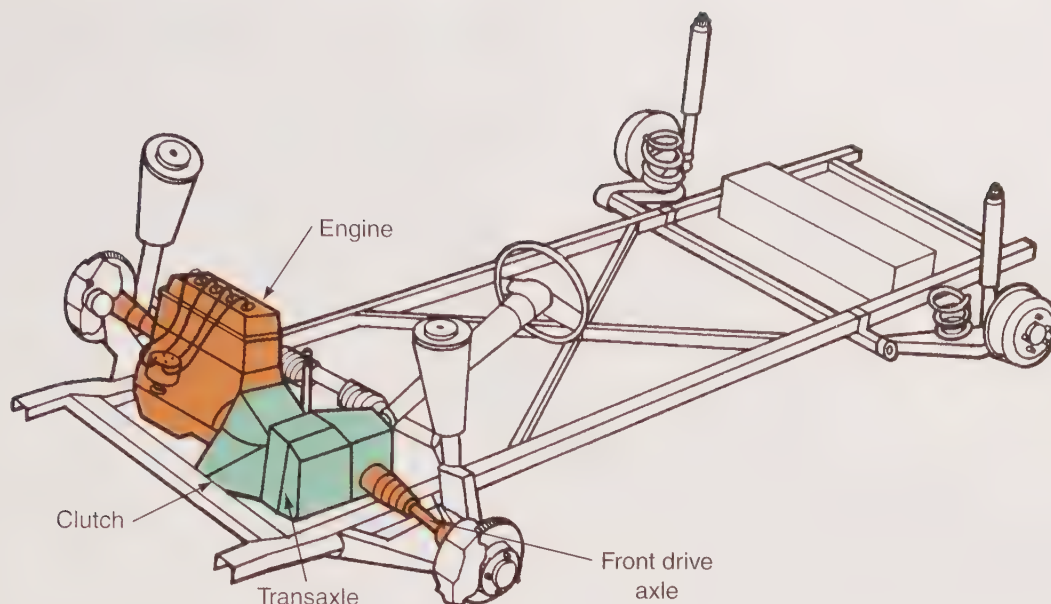


Figure 1-21. This shows how the drive train components of a front-wheel drive vehicle relate to the other parts. Note the relative positions of the engine, transaxle, and drive axles. (Ford)

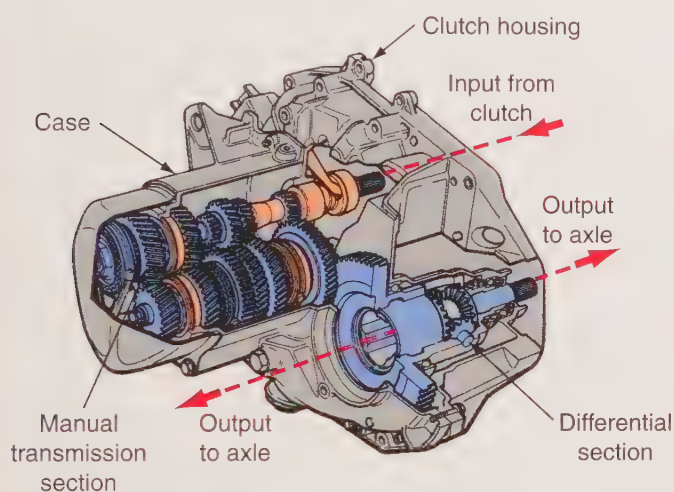


Figure 1-22. Common front-wheel drive manual transaxle. It contains a differential and manually operated transaxle gears. (Renault)

components. See **Figure 1-23**. A transfer case sends power to the rear drive shaft and, when desired, to the front drive shaft. The rear drive shaft attaches to a conventional rear axle assembly. The front drive shaft connects to a front axle assembly, which resembles the rear axle. It contains a differential assembly, with a ring and pinion. The front axles drive the front wheels.

The transfer case contains the mechanism to transmit power to all four wheels or to only the rear wheels. The transfer case may also contain extra reduction gears. The reduction gears provide a very low gear for heavy towing or off-road use. Some transfer cases are automatic in operation and can vary the amount of power sent to the front wheels, depending on vehicle needs. An automatic transfer case may contain a central differential or a viscous coupling, in addition to a

chain drive and various drive gears. An on-board computer controls many modern transfer cases. The computer may be a separate unit or may be part of the engine or drive train computer. Computer controlled transfer cases may contain small electric motors or solenoids to select the transfer case gears.

Summary

The drive train is a vital part of any vehicle. It sends power from the engine to the drive wheels. It may also modify this power so that the vehicle can be more versatile. There are many variations of drive trains. Most drive trains fall into several general classes.

The conventional rear-wheel drive system is used when a front-mounted engine drives the rear wheels. It was the most common kind of drive train for many years. The major drive train components are arranged in a straight line from the engine to the rear of the vehicle. The power flow is diverted 90° at the differential assembly.

The front engine, front-wheel drive system has become popular. The most common kind of front-wheel drive has a transverse engine. All drive components can be mounted in a straight line, and there is no need to turn the power flow 90° to drive the wheels. The components of the transmission and differential are combined in a single unit called a transaxle.

Rear- and mid-engine vehicles use a transaxle. In some cases, the engine is mounted behind the transaxle.

The four-wheel drive system can apply power to all of the wheels as needed. The transfer case, mounted behind the transmission, divides the power between the front and rear wheels. Some systems are manually operated by the driver, and some systems are automatic.

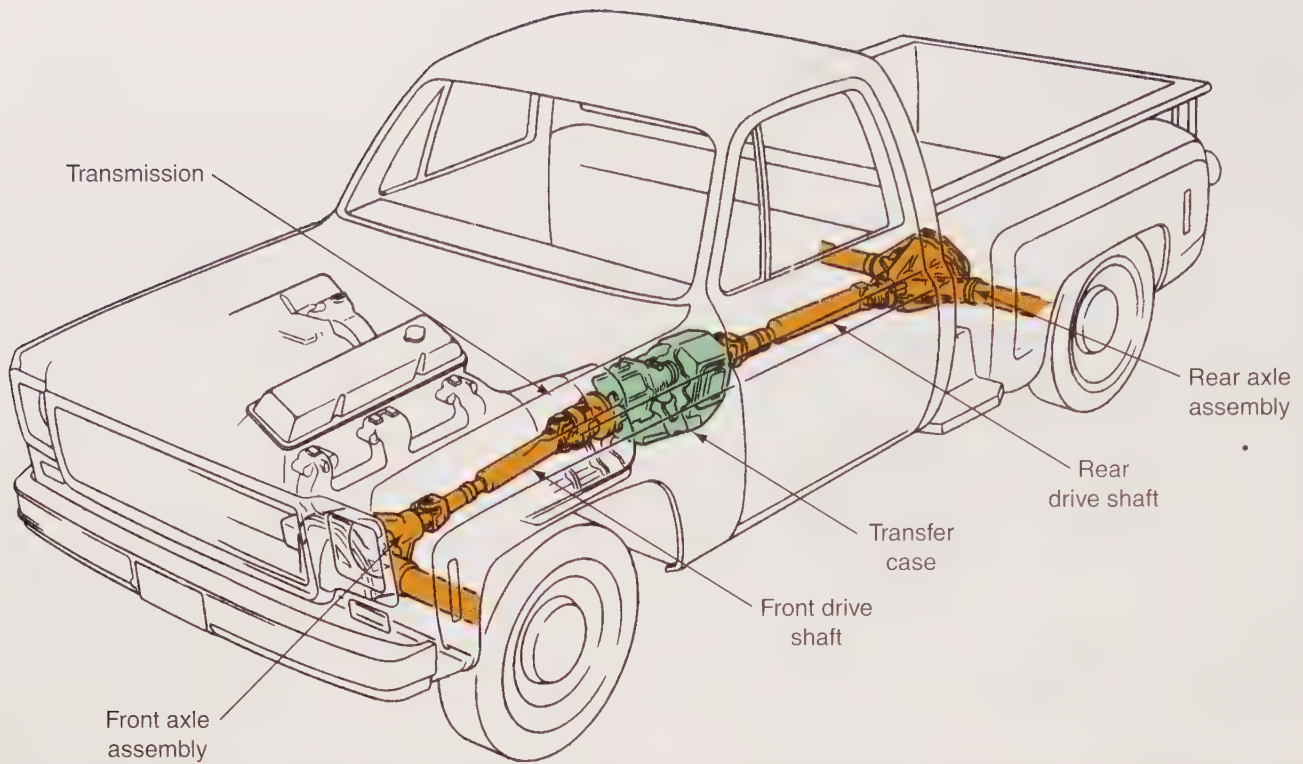


Figure 1-23. Four-wheel drive components. Note the dual drive shafts and that the front axle assembly resembles the rear axle assembly. The four-wheel drive can almost be thought of as two rear axles and two drive shafts tied together by the transfer case. Most major differences between makes of four-wheel drive vehicles occur in the transfer case. (General Motors)

Drive train components are similar no matter what type of drive train layout is used. The clutch connects and disconnects the engine from the transmission. The transmission is used to obtain different gear ratios and to allow the vehicle to be reversed when necessary.

The drive shaft transmits power from the transmission to the rear axle assembly. It uses a series of flexible joints to allow rear axle movement and eliminate vibration.

The rear axle assembly consists of a differential assembly and drive axles. The ring and pinion turns the power flow at right angles to drive the rear wheels and provides the proper gear ratio. The differential assembly also allows the rear wheels to turn at different speeds when making turns. Some rear axle assemblies have internal clutches to provide better traction.

The transaxle combines the functions of the transmission and differential into one unit, usually in a single case. Transaxles are used on front-wheel drive and rear- and mid-engine vehicles. Internal components resemble those used on the front-engine, rear-wheel drive train.

The four-wheel drive transfer case houses a number of gears. These gears can be used to send power to the rear wheels alone, or divide power between the front and rear wheels. Some transfer cases can provide a higher gear ratio when needed. Some have internal fluid couplings and send power to the front wheels only when needed. Many transfer cases are computer controlled.

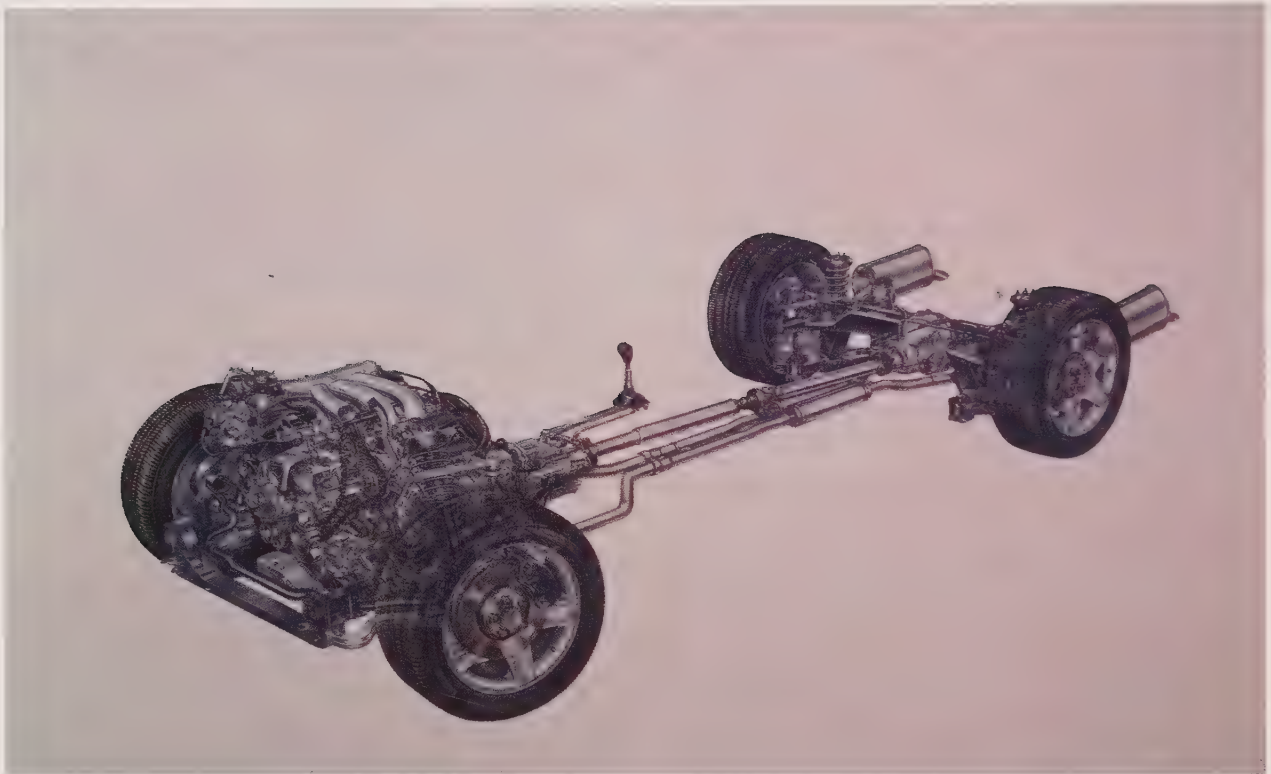
Review Questions—Chapter 1

Answer the following questions using the information provided in this chapter.

1. What is the basic function of a drive train?
2. The _____ and the _____ serve as ways to connect and disconnect the flow of power from engine to drive wheels.
3. What is the basic function of a rear axle assembly?
4. The _____ is sometimes called the final drive.
5. What is a transfer case?
6. Power flow through a rear-wheel drive rear axle takes a _____ turn.
7. The purpose of a transmission is to _____.
 - (A) reverse a vehicle
 - (B) provide high torque for starting off
 - (C) reduce engine rpm at higher speeds
 - (D) All of the above.
8. When do differential gears move in relation to each other?
9. A(n) _____ is a combination of a transmission and a differential assembly.
10. Why are Rzeppa joints commonly used on front-wheel drive cars?

ASE-Type Questions—Chapter 1

1. Technician A says that modern drive trains consist of various mechanical systems that form a path for engine power. Technician B says that drive trains having manual transmissions usually incorporate hydraulic systems, in addition to electronic systems. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
2. Which of the following components allows a vehicle's drive wheels to revolve at different speeds while turning corners?
 - (A) Engine.
 - (B) Slip yoke.
 - (C) Differential assembly.
 - (D) Torque converter.
3. Each of the following statements about a clutch is true *except*:
 - (A) it decides which drive gear to use.
 - (B) it is located directly behind the engine.
 - (C) it is almost always mounted on the engine flywheel.
 - (D) it connects and disconnects the engine from other drive train parts.
4. Each of the following functions is served by a transmission *except*:
 - (A) providing a low gear ratio during highway operation.
 - (B) splitting power at the transaxle differential.
 - (C) providing a high gear ratio for takeoff and acceleration.
 - (D) matching engine power and speed to vehicle conditions.
5. Which of the following components transmits power from the transmission to the rear axle assembly?
 - (A) CV joints.
 - (B) Driveline.
 - (C) Clutch.
 - (D) Differential assembly.
6. Which of the following components together makes up a manual transaxle?
 - (A) Transmission and torque converter.
 - (B) Transmission and differential assembly.
 - (C) Torque converter and differential assembly.
 - (D) Clutch and differential assembly.
7. Each of the following components may be found in a front-engine, rear-wheel drive system *except*:
 - (A) a clutch.
 - (B) a transaxle.
 - (C) a transmission.
 - (D) shift linkage.
8. Each of the following components is part of the drive shaft assembly *except*:
 - (A) a ring and pinion.
 - (B) a slip yoke.
 - (C) universal joints.
 - (D) a drive shaft.
9. Technician A says that all rear axle bearings are packed with grease at the factory. Technician B says that rear axle bearings may be lubricated by grease or oil splash. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
10. Which of the following components is *not* found on a drive train where the vehicle engine is transverse mounted?
 - (A) U-joints.
 - (B) CV joints.
 - (C) Rzeppa joints.
 - (D) Hypoid gearing.



Chassis view of a front-engine, rear-wheel drive system with a 5-speed manual transmission. (Ford)



Chapter 2

Shop Safety and Environmental Protection

After studying this chapter, you will be able to:

- ☐ Identify the major causes of accidents.
- ☐ Explain why accidents must be avoided.
- ☐ List ways to maintain a safe workplace.
- ☐ List safe work procedures.
- ☐ Identify types of environmental damage caused by improper auto shop practices.
- ☐ Identify ways to prevent environmental damage.

Technical Terms

Material Safety Data Sheets (MSDS)

Safety areas

Eyewash station

Safety glasses

Face shield

Environmental damage

Core value

Refrigerants

Environmental Protection Agency (EPA)

Introduction

There are many ways to do a job in an unsafe manner, and usually only one way to do it safely. The reason to make repairs in a safe manner is it protects the technician, the vehicle, and the shop. This chapter covers reasons for and methods of doing things safely. Also covered in this chapter is the proper handling and disposal of waste products. Wastes must be handled properly to safeguard both the technician and the environment. This chapter examines various types of unsafe conditions and work practices, and environmental violations, and explains how to correct or avoid them.

Causes of Accidents

No normal person tries to cause an accident. Accidents result in injuries that keep you from working or enjoying your time off. Some accidents can kill. Even slight injuries are painful and annoying, and may impair your ability to work and play. Even if an accident causes no personal injury, it can result in property damage. Damage to vehicles or shop equipment can be expensive and time consuming to fix, and could even cost you your job.

The ways that you can have an accident in the shop are many and varied. Most accidents are caused by one of two factors:

- ☐ Failure to maintain a safe workplace.
- ☐ Performing service procedures improperly.

Examples of failure to maintain a safe workplace are failing to properly maintain tools and equipment; allowing old parts, containers, or other trash to lie around the shop; and ignoring water or oil spills.

Examples of improper service procedures are using the wrong tools or methods to perform repairs, using defective or otherwise inappropriate tools, not wearing protective equipment when necessary, and not paying close attention while performing the job.

In both examples, carelessness plays a major role in contributing to accidents. The usual cause of accidents is the attitude that it is just too much trouble to do things correctly. The end result of this attitude is an accident. Unfortunately, even experienced technicians become rushed and careless. Therefore, falls, injuries to hands and feet, fires, explosions, electric shocks, and even poisonings occur in auto repair shops. Carelessness in the shop can also lead to long-term bodily harm from prolonged contact with harmful liquids, vapors, and toxic dust. Lung damage, skin disorders, and even cancer can result from contact from these substances. For these reasons, the technician must keep safety in mind at all times, especially when conditions tend to make it the last thing on his or her mind.

Do not let carelessness make you a casualty. Be sure to maintain a neat workplace, use safe methods and common sense when making repairs, and wear protective equipment when needed. The following are some suggestions for reducing the possibility of accidents.

Maintaining a Safe Workplace

Return all tools and equipment to their proper storage places. See **Figure 2-1**. This saves time in the long run and reduces the chance of accidents and theft. Do not leave any equipment out where others could trip.

Keep workbenches clean. This reduces the chance of tools or parts falling from the bench onto the floor, where they could be lost or damaged. A falling tool or part could land on your foot. A clean workbench also reduces the



Figure 2-1. Keep your tools clean and arranged in an easy-to-find manner. (Snap-on Tool Corp.)

possibility that critical parts will be lost in the clutter, or that a fire will start in oily debris.

Clean up spills immediately, before they get tracked around the shop. Many people are injured when they slip on floors coated with oil, antifreeze, or water. Gasoline spills can be extremely dangerous since a flame, cigarette, or the smallest spark can ignite the vapors, causing a major explosion and fire.

Know what chemicals are stored on the shop premises. Chemicals include carburetor cleaners, hot tank

solutions, parts cleaner, and even motor oil and anti-freeze. Chemical manufacturers provide **Material Safety Data Sheets**, often called **MSDS**, for every chemical they produce. These sheets list all of the known dangers of the chemical, as well as first aid procedures for skin or respiratory system contact. There should be an MSDS for every type of chemical used in the shop. Read the MSDS before working with any unfamiliar chemical. **Figure 2-2** shows a typical MSDS.

ACME Chemical Company	
Material Safety Data Sheet	
Product Name: Acetylene	
24-hour Emergency Phone: Chemtrec 1-800-424-9300	Outside United States 1-905-501-0802
Trade Name/Syn: Acetylene	NFPA Ratings
Chemical Name/Syn: Acetylene, Ethyne, Acetylen, Ethine	Health: 0
CAS Number: 74-86-2	Flammability: 4
Formula: C ₂ H ₂	Reactivity: 0
Hazards Identification	
Simple Asphyxiant. This product does not contain oxygen and may cause asphyxia if released in a confined area. Maintain oxygen levels above 19.5%. May cause anesthetic effect. Highly flammable under pressure. Spontaneous combustion in air at pressures above 15 psi. Acetylene liquid is shock sensitive.	
Effects of Exposure-Toxicity-Route of Entry	
Toxic by inhalation. May cause irritation of the eyes and skin. May cause an anesthetic effect. At high concentrations, excludes an adequate oxygen supply to the lungs. Inhalation of high vapor concentrations causes rapid breathing, diminished mental alertness, impaired muscle coordination, faulty judgment, depression of sensations, emotional instability, and fatigue. Continued exposure may cause nausea, vomiting, prostration, loss of consciousness, eventually leading to convulsions, coma, and death.	
Hazardous Decomposition Product	
Carbon, hydrogen, carbon monoxide may be produced from burning.	
Hazardous Polymerization	
Can occur if acetylene is exposed to 250°F (121°C) at high pressures or at low pressures in the presence of a catalyst. Polymerization can lead to heat release, possibly causing ignition and decomposition.	
Stability	
Unstable—shock sensitive in its liquid form. Do not expose cylinder to shock or heat, do not allow free gas to exceed 15 psig.	
Fire and Explosion Hazard	
Pure acetylene can explode by decomposition above 15 psig; therefore the UEL is 100% if the ignition source is of sufficient intensity. Spontaneously combustible in air at pressures above 15 psi (207 kPa). Requires very low ignition source. Does not readily dissipate, has density similar to air. Gas may travel to source of ignition and flash back, possibly with explosive force.	
Conditions to Avoid	
Contact with open flame and hot surfaces, physical shock. Contact with copper, mercury, silver, brasses containing >66% copper and brazing materials containing silver or copper.	
Accidental Release Measures	
Evacuate all personnel from affected areas. Use appropriate protective equipment. Shut off all ignition sources. Stop leak by closing valve. Keep cylinders cool.	
Ventilation, Respiratory, and Protective Equipment	
General room ventilation and local exhaust to prevent accumulation and to maintain oxygen levels above 19.5%. Mechanical ventilation should be designed in accordance with electrical codes. Positive pressure air line with full face mask or SCBA. Safety goggles or glasses, PVC or rubber gloves in laboratory; and as required for cutting or welding, safety shoes.	

Figure 2-2. This Material Safety Data Sheet (MSDS) is for acetylene.

Make sure the shop is well lighted. Poor lighting makes it hard to see what you are doing, leading to accidental contact with moving parts or hot surfaces. Overhead lights should be bright and centrally located. Portable lights, or droplights, should be in operating condition and easy to use. Droplight cages should be in place. Always use a "rough service" bulb, **Figure 2-3**, in incandescent droplights. These bulbs are more rugged than normal lightbulbs and will not shatter if they break. Do not use a high wattage bulb in a droplight. Lightbulbs get very hot and can melt the light socket or cause burns.

Do not overload electrical outlets or extension cords by operating several electrical devices from one outlet. An overloaded outlet is shown in **Figure 2-4**. Do not operate high current electrical devices through extension cords.

Frequently inspect electrical cords and compressed air lines to ensure they are in good condition. Also look for improper air hose connections, **Figure 2-5**. Do not close vehicle doors on electric cords or air hoses. Do not run electrical cords through water puddles or use them outside when it is raining.



Figure 2-3. Always use a rough-service bulb in a droplight. Keep the cage closed.

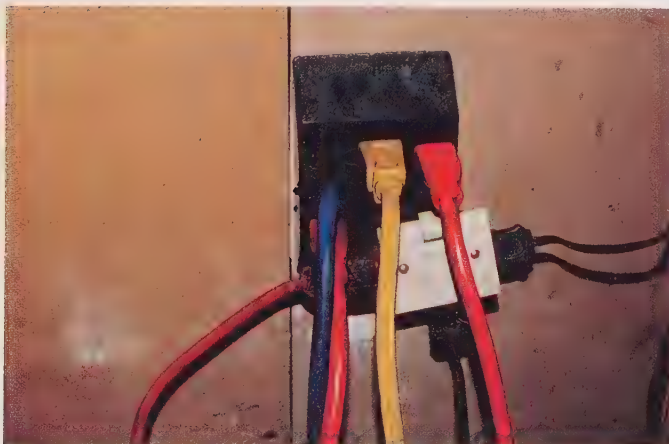


Figure 2-4. An overloaded electrical outlet poses a fire risk.

Ensure that all shop equipment, such as grinders and drill presses, is equipped with safety guards, **Figure 2-6**. All shop equipment is equipped with guards by the manufacturer. These guards should never be removed, except for service operations such as changing the grinding wheels.

When servicing any shop equipment, be sure the equipment is turned off and unplugged. Read the equipment service literature before beginning any repairs.

Closely monitor tool and equipment condition and make repairs when necessary. This includes replacing damaged leads on test equipment, checking and adding oil to hydraulic jacks, and regrinding the tips on screwdrivers and chisels.

Do not leave open containers of antifreeze in the shop or outside. Ethylene glycol antifreeze will poison any animal (or person) who drinks it, and spills will create an extremely slippery floor.

Know where the shop fire extinguishers are located and know how to operate them. Make sure you know what type of fire extinguisher is used on what type of fire. The chart in **Figure 2-7** shows the kinds of extinguishers and the fires they will extinguish. Regularly check that the fire



Figure 2-5. Not only is this hose bulged and oil soaked, it is improperly attached to the coupler with a hose clamp. This hose should be replaced.

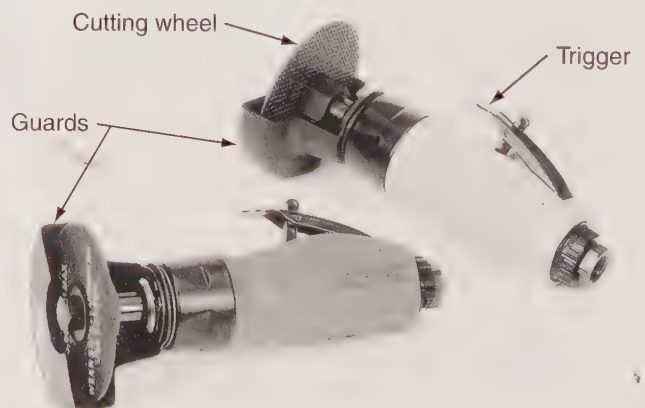


Figure 2-6. An air-operated cutter set. Note the use of safety guards. These tools operate at speeds up to 20,000 rpm. Wear safety glasses when using power tools. (Snap-on Tool Corp.)

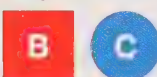
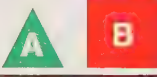
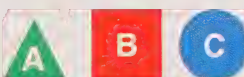
Fires	Type	Use	Operation					
Class A Fires Ordinary Combustibles (Materials such as wood, paper, textiles.) <i>Requires... cooling-quenching</i> Old New  	Soda-acid Bicarbonate of soda solution and sulfuric acid 	Okay for use on  Not for use on 	Direct stream at base of flame.					
Class B Fires Flammable Liquids (Liquids such as grease, gasoline, oils, and paints.) <i>Requires...blanketing or smothering.</i> Old New  	Pressurized Water Water under pressure 	Okay for use on  Not for use on 	Direct stream at base of flame.					
Class C Fires Electrical Equipment (Motors, switches, etc.) <i>Requires... a nonconducting agent.</i> Old New  	Carbon Dioxide (CO₂) Carbon dioxide (CO ₂) gas under pressure 	Okay for use on  Not for use on 	Direct discharge as close to fire as possible, first at edge of flames and gradually forward and upward.					
Class D Fires Combustible Metals (Flammable metals such as magnesium and lithium.) <i>Requires...blanketing or smothering.</i> 	Foam Solution of aluminum sulfate and bicarbonate of soda 	Okay for use on  Not for use on 	Direct stream into the burning material or liquid. Allow foam to fall lightly on fire.					
	Dry Chemical 	<table><tr><td>Multi-purpose type</td><td>Ordinary BC type</td></tr><tr><td>Okay for </td><td>Okay for </td></tr><tr><td>Not okay for </td><td>Not okay for </td></tr></table>	Multi-purpose type	Ordinary BC type	Okay for 	Okay for 	Not okay for 	Not okay for 
Multi-purpose type	Ordinary BC type							
Okay for 	Okay for 							
Not okay for 	Not okay for 							
	Dry Chemical Granular type material	Okay for use on  Not for use on 	Smother flames by scooping granular material from bucket onto burning metal.					

Figure 2-7. A chart showing fire and fire extinguisher classifications. The proper extinguisher must be used to effectively put out fires. Using the wrong extinguisher may lead to electrocution.

extinguishers are in working order and have them checked regularly by qualified personnel.

Do not allow oily rags to collect in the shop. Oily rags can begin to decay and build up heat. If enough heat builds up, the rags can ignite in a process called spontaneous combustion. Always place oily rags in airtight containers made to contain a fire.

Many areas in the average automotive shop have extra dangers. These dangers include equipment with moving parts, vehicle lifts, cleaning equipment, and areas for storing chemicals. These are designated as **safety areas**, or areas where extra alertness and safety precautions are needed. Safety areas are called out by signs, warning symbols, and highly visible floor markings using colors such as red or yellow. Often safety area floors are painted with alternating stripes.

When encountering any signs, symbols, or paint indicating a safety area, avoid entering the area unnecessarily. If it is necessary to enter a safety area, wear protective equipment as needed and be alert to the dangers.

Performing Work Procedures Properly

The following work procedures may add time to the job, but will make your job and your life easier.

Do not wear open jackets, scarves, or shirts with long, loose sleeves. They can get caught in moving parts.

If you wear your hair long, keep it away from moving parts by securing it under a hat or sweatband.

Remove any rings or other jewelry to keep it from being caught in moving parts or causing a short circuit if the metal parts get between a positive terminal and ground.

Wear eye protection when working in any situation that could result in dirt, metal, or liquids being thrown into your face. **Safety glasses** protect your eyes from flying metal and dirt. A **face shield** provides protection when working with solvents or other harmful liquids.

If contaminants do get in your eyes, they should be removed as soon as possible. This can be done by flushing your eyes using an **eyewash station**.

Eyewash stations should be located in well-lit areas and identified by signs. If possible they should be no more than ten-seconds walking distance from any work area. Eyewash stations should not be blocked by vehicles, boxes, parts, or anything else that prevents easy access. The dust covers over the eyewash nozzles should be left in place except when the eyewash station is actually in use.

To use an eyewash station, remove the nozzle dust covers and open the water flow valve. Hold your eyelids open with your fingers and allow the maximum amount of water to flow into your eyes. If necessary ask for assistance holding your eyelids open. Do not rub your eyes. If only one eye is involved, hold your head so that the rinsing water does not enter the unaffected eye. Allow water to flow for at least 15 minutes. Extra time may be needed if your eyes have been contaminated with extremely acidic or caustic liquids. After your eyes have been thoroughly flushed, seek medical attention.

Wear safety shoes, preferably with steel toe inserts, when there is any danger of falling parts or tools. Since such an incident can occur at any time, it is a good idea to wear safety shoes whenever you are in the shop.

Wear rubber gloves when working with solvents such as parts cleaning solvents or carburetor cleaner.

During an emergency that could affect personal safety, it is important to know the quickest route to exit the shop. All shops should have clearly marked evacuation routes and exits. Diagrams showing evacuation routes should be posted in several areas in the shop. Study the diagram upon first entering the shop. If an emergency occurs, follow the marked routes to leave the shop. Leave immediately. Do not stop to retrieve belongings or for any other reason. Do not reenter the building until it is safe to do so.

Study work procedures before beginning any job that is unfamiliar. Do not assume the procedure you have used in the past will work with a different type of vehicle.

Always work carefully. Speed is not nearly as important as doing the job right and avoiding injury. Avoid coworkers who will not work carefully or who tend to engage in horseplay.

Use the right tool for the job. Using the wrong tool for the job is asking for an accident, or at least a broken tool. Never use a 12-point hand socket with an impact wrench. Do not use low quality tools or tools that are damaged.

Learn how to use new equipment before using it. This is especially true of impact wrenches, air chisels, and other air-operated tools. It is also true for large electrical devices such as drill presses and brake lathes. These tools are very powerful and can hurt you badly if they are used improperly. A good way to learn about new equipment is to start by reading the manufacturer's instructions.

When working on electrical systems, avoid creating a short circuit with a jumper wire or metal tool. Not only will this damage the vehicle components or wiring, it will develop enough heat to cause a severe burn or start a fire.

Electrical systems in older vehicles operated on vehicle battery power, and technicians did not have to worry about electrical injury. Modern vehicles, however, have various electrical systems that operate on high voltage and current, which can cause injury or even death. Hybrid vehicle batteries produce hundreds of amps of current and more than 600 volts, while direct fuel injection systems can develop as many as 10 amps and 100 volts. High intensity discharge (HID) lamps may produce thousands of volts. These voltages are often present even when the vehicle is not running. The technician must be aware of these high voltages and understand how to work safely around such voltages.

Always follow recommended service procedures when working on any high-voltage system. Wear insulated rubber gloves when removing any high-voltage electric device or connector. Do not lean against the vehicle while working on any high-voltage device, as this could complete a circuit between the positive and negative circuits of the device. Always wear insulated rubber gloves when working on any high-voltage electrical components.

Special precautions must be taken when working on hybrid vehicle high-voltage circuits. Consult the manufacturer's service information to identify and locate the vehicle high- and low-voltage circuits and components. The high-voltage cables on most hybrid vehicles are covered with orange insulation for easy identification, as in **Figure 2-8**.



Warning: Never assume that a discharged high-voltage battery is safe. A high-voltage battery that will no longer operate the vehicle may still produce several hundred volts of electricity.

Next, check the vehicle service information for the exact location of the disconnect device. The shape and location of a typical service disconnect plug is shown in **Figure 2-9**. On some vehicles, removing the auxiliary battery negative terminal clamp will disable the high-voltage circuits. On other vehicles, it may be necessary to remove a clearly marked service disconnect plug or a high-voltage circuit control fuse or control relay specifically designed to disable the high-voltage system. Be sure to wear insulated rubber gloves when removing any high-voltage electrical components.

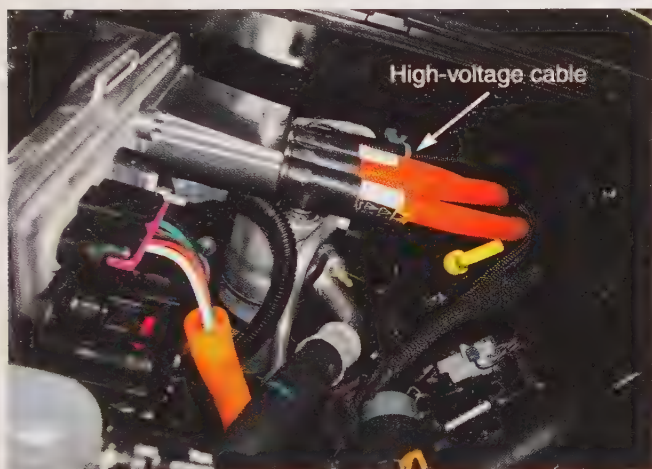


Figure 2-8. Hybrid vehicles have orange insulation around high-voltage cables for easy identification. (Toyota)

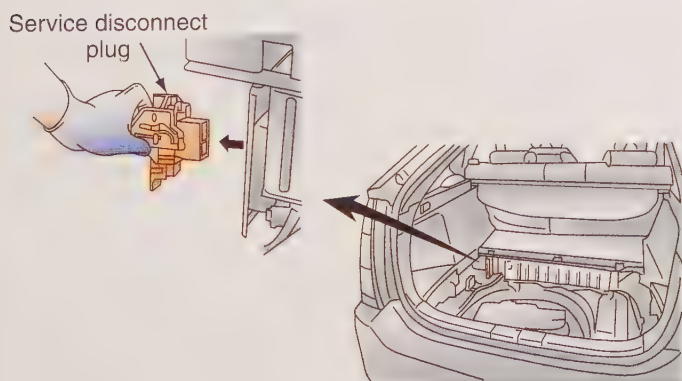


Figure 2-9. Before working on the electrical system in a hybrid vehicle, locate and remove the service disconnect plug. (Toyota)

Wait at least five minutes to allow the high-voltage components to discharge fully, and then use a voltmeter or multimeter to check for voltage at the high-voltage cables. Less than 12 volts is considered safe. After repairs are completed, reinstall the applicable device to restore high voltage to the vehicle.

Lift safely. Make sure you are strong enough to lift the object to be moved. Always lift with your legs, not your back. If an object is too heavy to lift by yourself, get help.

Do not smoke in the shop. You may accidentally ignite an unnoticed gasoline leak. A burning cigarette may also ignite oily rags or paper cartons.

Careless use of vehicle jacks and lifts can lead to injury or death. Never attempt to raise a vehicle with an unsafe or under-capacity jack. Always support a raised vehicle with good quality jack stands. Never use boards or cement blocks to support a vehicle.

Before using a jack to lift a vehicle, look under the vehicle to locate a lift point that is strong enough to support the vehicle weight. Acceptable lift points typically include frame or engine cradle sections, strengthened sections of unibody vehicles, lower control arms, and differential housings. Vehicle manufacturers illustrate correct lift points in their manuals. Never raise a vehicle by jack using the oil pan, transmission, steering parts, gas tank, or other drivetrain component as a lift point. Be sure to account for weight distribution when lifting any vehicle. Front-wheel drive vehicles are heavier toward the front axle than rear-wheel drive vehicles.

Operate the jack to slowly raise the vehicle, being sure that it lifts evenly and solidly contacts the vehicle. If the jack saddle slips or body parts are being distorted, immediately lower the vehicle and reposition the jack.

Once the vehicle has been raised to the desired height, place jack stands under it. The jack stands should be placed with the same care as the jack. Be sure that the stands will not slip or damage the vehicle. Then lower the vehicle onto the stands. The jack may then be removed if desired. If not needed in another area, the jack may be left in position with a very light lifting pressure to keep it in place.

Before lowering a vehicle, check for equipment, parts, and persons underneath the vehicle. Use the jack to raise the vehicle slightly to remove the weight from the jack stands. Remove the jack stands, making sure that they completely clear the vehicle. Then slowly lower the vehicle, watching it closely during the entire descent.

Before using a vehicle lift, check it for cracked or bent parts, faulty safety locks, and leaking hydraulic cylinder(s). Move the lift arms to the sides and drive the vehicle onto the lift. Make sure it is in the proper position. Then position the lift saddles so they securely contact the vehicle's chassis, being sure to allow for weight distribution when lifting any vehicle. Once saddles are positioned, raise the vehicle until its wheels just clear the ground. Then try to rock the vehicle on the lift. If the vehicle rocks excessively or the saddles are not positioned properly, immediately lower the vehicle and reposition the saddles before proceeding.

Watch for side or overhead obstructions as the vehicle is being raised. When the vehicle is fully raised, check the

safety lock for full engagement before going under the vehicle. Never raise or lower a vehicle when a person is under it.

Before lowering a raised vehicle, check for equipment, parts, and personnel below the vehicle. Always lower the vehicle slowly and watch it closely during the entire descent.

Precautions must be taken when performing certain service procedures on vehicles equipped with air bag systems, or supplemental restraint systems (SRS). When there is a chance of electrical power entering any air bag electrical component, disconnect or remove the air bag module before servicing the vehicle.

To remove an air bag module, begin by removing the battery negative cable. Wait at least ten minutes for the system to electrically discharge and then disconnect the module's electrical connectors. Finally, remove the fasteners securing the module and remove the module from the vehicle.



Caution: Never swap air bag components between vehicles.

When carrying a live (undeployed) inflator module, hold it securely with both hands and make sure the bag (trim cover side) is pointed away from your body. When placing a live module on a workbench or other surface, the bag and trim cover should be facing up. Never place anything on or near the module that could be thrown in the event of an accidental deployment. Never throw an undeployed module in the trash. Follow the vehicle manufacturer's recommended procedures to discharge the module before disposal.

When necessary to clean powder residue from a vehicle's interior after air bag deployment, wear safety glasses, rubber gloves, and long-sleeved clothing. Vacuum the powder. Do not blow the powder from the vehicle with compressed air.

When servicing vehicles with anti-lock brakes (ABS) or traction control (TCS) systems, check the service information for any safety-related procedures. Some systems are inoperative when the engine is off, while other systems may hold pressure in the lines and other components for an indefinite amount of time. The ABS/TCS system may need to be depressurized before loosening bleeder valves or hydraulic lines. If this is not done, fluid could spray out with great force.

Do not run any type of engine, even for a short time, in a closed area without good ventilation. Carbon monoxide builds up quickly and cannot be detected.

When working on or near a running engine, keep away from all moving parts. Never reach between moving engine parts for any reason.

Do not leave a running vehicle unattended. The vehicle may slip into gear or overheat while you are away. Whenever you must work on a running vehicle, apply the parking brake.

When road testing a vehicle, be alert and obey all traffic laws. Do not become so absorbed in diagnosing a problem that you forget to watch the road. Be alert for the actions of other drivers.

Environmental Damage

Automotive repair shops can cause **environmental damage**. Shops are often guilty of carelessly disposing of solid and liquid wastes and of causing damage to the atmosphere by improper repair procedures.

Typical solid wastes produced by automotive repair shops are scrap parts, tires, and cardboard boxes. Liquid wastes include antifreeze, brake fluid, cleaning solvents, motor oil, and transmission fluid.

Improper repair procedures include allowing refrigerant gases to escape into the atmosphere and repairing engines so that they emit excessive amounts of pollutants.

Allowing these practices to continue lowers the quality of our lives by contaminating the air we breathe, the water we drink, and the earth where our food grows. If we ignore the effect of irresponsible waste production and dumping, the economic burden of dealing with waste will grow ever larger, and our descendants will have to deal with the problem.

The following are a few suggestions for dealing with solid wastes. In certain parts of the United States, some of these are rigidly enforced laws, rather than suggestions.

Preventing Solid Waste Contamination

Do not allow solid wastes to build up around the shop. It is unsightly, dangerous, and expensive. Recycle parts and scrap materials whenever possible. Do not throw away parts boxes, old tires, and salable scrap metals unless you are sure they cannot be recycled. It makes good economic sense to recycle since almost every rebuildable part has a return value, usually called a **core value**. The value of paper, scrap tires, and scrap metals such as aluminum, iron, and brass depends on the current market conditions, but these items always have some value. Check with your local parts supplier to determine which parts can be sent back for rebuilding. Rebuildable parts include alternators, coolant pumps, and clutch pressure plates. Recyclers are often listed in the telephone book and can give you advice on what to do with recyclable materials. If solid wastes cannot be recycled, dispose of them responsibly, not by illegal dumping or burning.

Preventing Liquid Waste Contamination

Probably the most common way that an automotive shop damages the environment is by pouring used motor oil, transmission fluid, antifreeze, brake fluid, or gear oil on the ground. This immediately contaminates the soil. In addition, these liquids sink further into the ground every time it rains, eventually contaminating the water table. This could be your local drinking water source. Do not pour liquid wastes into drains. Municipal waste treatment plants cannot handle antifreeze, brake fluid, or petroleum products. Most liquids also contain poisonous additives and heavy metals absorbed from the vehicle during use. In most areas, such dumping is illegal.

In many areas, local waste management companies will accept used oil and antifreeze for recycling. Several 55-gallon drums should be kept in the shop to store liquid wastes. The used oil and antifreeze is then re-refined and reused. Some used oil is burned by power plants to produce electricity, eliminating the oil and reducing the dependence on imported crude oil.

Preventing Damage to the Atmosphere

The main way in which automotive shops hurt the atmosphere is by making modifications that damage or defeat the purpose of the vehicle emission control systems. Adjusting carburetors for a richer mixture, changing the manufacturer's timing settings, and disconnecting emission controls will increase emissions. Some seemingly harmless actions, such as installing a lower temperature cooling system thermostat or a nonstock air cleaner, can also cause a rise in engine and vehicle emissions. Not only are these actions illegal, they almost never increase power and mileage as much as hoped.

Do not discharge air conditioner **refrigerant** into the atmosphere. Studies have shown that refrigerants such as R-12 cause extensive damage to the ozone layer, leading to increased ultraviolet ray damage. Even "safe" refrigerants, such as R-22 and R-134a, contribute to ozone layer loss. This is another area covered by federal and, in some cases, state laws. However, replacing refrigerants costs money. For instance, R-12 refrigerant costs over seven times as much as it did just a few years ago. It makes good economic sense to recover and reuse refrigerants. If you do not have a machine that can recover and recycle refrigerant, send the customer to a shop that can do the job properly.

The Environmental Protection Agency

Modifying, disabling, removing, or otherwise tampering with engine emission controls is a federal crime with severe penalties. Vehicle emissions laws are enforced by the **Environmental Protection Agency**, usually called the **EPA**. The EPA investigates suspected violations and often conducts "sting" operations to catch violators. In addition, some states, such as California, have additional laws protecting the environment.

Additional information about waste disposal and vehicle emissions can be obtained from the Environmental Protection Agency. The EPA has ten regional offices and six field offices throughout the U.S. For the address of the nearest EPA office, write, call, or visit the EPA Web site:

Automotive/Emissions Division
United States Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460
(202) 260-2090
www.epa.gov

Accidents are not inevitable. It is up to you to notice and correct safety hazards and use safe work practices. This is the only way to prevent accidents. It is also up to you to eliminate environmental damage by taking the proper steps to reduce the improper disposal of wastes. Always use common sense when working in the shop, and avoid people who do not.

Summary

Carelessness plays a major role in contributing to accidents. Many technicians get in a hurry and forget to do the job safely. An accident may result in personal injuries, long-term bodily harm, or injuries to equipment or property. No mature and competent automotive technician wants to be injured or cause property damage.

Many accidents are caused when technicians fail to correct dangerous conditions in the work area, such as oil spills or tripping hazards. Other accidents are caused when technicians try to take shortcuts instead of following proper repair procedures. The best way to prevent accidents is to maintain a neat workplace, use proper methods of repair, and use protective equipment when needed. It is up to the technician to study the job beforehand, work safely, and prevent accidents. Always use common sense when working on vehicles, and avoid people who do not.

Careless production and disposal of wastes cause much environmental damage. Wastes can take the form of liquids, solids, or gases. Anyone or any shop can be a cause of pollution. The two main ways an automotive shop can cause environmental damage are carelessly disposing of wastes and repairing vehicles in such a way that they pollute the atmosphere.

Environmental rules should always be followed to prevent damage to the air, water, or soil. In many cases, federal and state law requires proper disposal of wastes and proper vehicle repairs.

Review Questions—Chapter 2

Answer the following questions using the information provided in this chapter.

1. An accident can cause _____ injury and can result in damage to _____.
2. What attitude is the usual cause of accidents?
3. Give some examples of failure to maintain a safe workplace.
4. Give some examples of improper service procedures.
5. Returning tools to their storage places saves _____ in the long run.
6. What could happen if a ring or bracelet gets between a positive terminal and ground?
7. _____ builds up quickly and cannot be detected.

8. When working on a running vehicle, you should do all of the following *except*:
 - (A) apply the parking brake.
 - (B) work in a well-ventilated area.
 - (C) leave the car unattended.
 - (D) keep away from all moving parts.
9. Almost every rebuildable part has a _____.
10. Vehicle emission laws are enforced by the _____.

ASE-Type Questions—Chapter 2

1. Technician A says that one way to prevent accidents is to avoid people who are careless. Technician B says that one way to prevent accidents is to keep an orderly workplace. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
2. A new steam cleaner has just been delivered. What should the technician do first?
 - (A) Read the instruction manual.
 - (B) Plug in the cleaner, and make sure it works.
 - (C) Add water and soap to the water tank.
 - (D) Add fuel, unless it is an electric model.
3. A Material Safety Data Sheet is provided for each of the following products listed below *except*:
 - (A) motor oil.
 - (B) parts cleaner.
 - (C) coil springs.
 - (D) antifreeze.
4. If all tools and equipment are returned to their proper storage places, which of the following will occur?
 - (A) They will be hard to find the next time.
 - (B) They will be easier to steal.
 - (C) They cannot be tripped over.
 - (D) All of the above.
5. When should you use a 12-point socket with an impact wrench?
 - (A) When an impact socket is not available.
 - (B) When the bolt to be removed is not very tight.
 - (C) When the air supply to the impact wrench is weak.
 - (D) Never.
6. A "rough service" lightbulb will reduce the chances of which of the following?
 - (A) Shorts in the droplight.
 - (B) Shattering if broken.
 - (C) Poor lighting.
 - (D) Tripped circuit breakers.
7. Spilled ethylene glycol antifreeze can cause each of the following *except*:
 - (A) slipping.
 - (B) poisoning.
 - (C) fires.
 - (D) environmental damage.
8. Eyewash station use is being discussed. Technician A says that you should allow water to flow into your eyes for at least 15 minutes. Technician B says that you should hold your eyelids open with your fingers to allow the maximum amount of water to flow into your eyes. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
9. Do not become so absorbed in diagnosing a problem that you forget to _____.
 - (A) come back
 - (B) watch the gauges
 - (C) watch the road
 - (D) watch the customer
10. An automotive shop can cause environmental damage by doing each of the following *except*:
 - (A) recycling parts.
 - (B) carelessly disposing of wastes.
 - (C) repairing vehicles so that they pollute the atmosphere.
 - (D) discharging refrigerants into the atmosphere.



Chapter 3

Special Service Tools

After studying this chapter, you will be able to:

- ☐ Identify special tools used in drive train service.
- ☐ Identify drive train measuring tools.
- ☐ Identify common electrical/electronic test equipment.
- ☐ Identify types of service literature.
- ☐ Select the right tool for the job at hand.
- ☐ Identify right and wrong ways to use certain types of tools.

Technical Terms

Special service tools	Screw extractors	Torque wrench
Spanner wrench	Holding fixtures	Preload
Punches	Transmission jacks	Jumper wire
Drifts	Parts washers	Test lights
Snap ring pliers	Gauges	Multimeter
Picks	Size gauge	Waveform meter
Interference fit	Micrometer	Scan tool
Press fit	Feeler gauge	Fender covers
Press	Outside micrometer	Steering wheel cover
Drivers	Hole gauge	Seat cover
Pullers	Telescoping gauge	Service literature
Seal protector	Inside micrometer	Diagnosis manual
Alignment tool	Depth micrometer	Overhaul manual
Flywheel turner	Calipers	Schematic
Flywheel holder	Straightedge	Troubleshooting chart
Drain pan	Dial indicator	Telephone hotline
	Angle gauge	Work orders

Introduction

This chapter identifies and explains special tools and equipment used to service drive trains. It discusses the ways tools and equipment can be used in specific drive train diagnostic and repair operations and discusses the types of service literature available.

Drive Train Service Tools

In addition to the normal hand tools used in repair shops, **special service tools** are needed to service parts of the drive train. These tools are exclusively designed to service a specific component or a specific class of components. This contrasts with the usual hand tools designed to be used on many parts for many purposes. Spanner wrenches, snap ring pliers, drivers, and pullers are examples of special service tools.

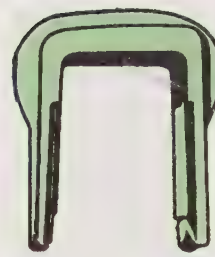
As mentioned, some special service tools are designed to service a specific component. Many of these have to be obtained through the tool or vehicle manufacturer. These tools are identified in vehicle service manuals, usually in the back of the manual. **Figure 3-1** shows some of the special service tools used to service drive train components of rear-wheel drive vehicles. **Figure 3-2** shows some of the tools that could be used for front-wheel drive transaxles. The part number appearing with each tool is a coded description of that tool. This number is specified when ordering.

Service manuals also contain information on when to use a tool and how to use it properly. Most service manuals also contain the address for the manufacturer of the tools and information on how to order tools. Prices of special service tools can be obtained from the tool manufacturer. In some cases, these tools must be ordered through the vehicle manufacturer, as mentioned.

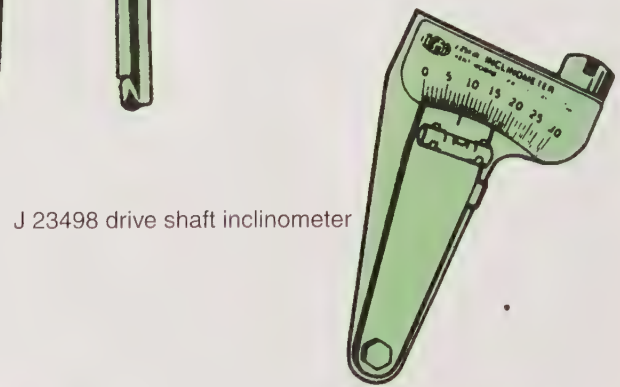
Special Service Wrenches and Sockets

Wrenches are tools used to grip and turn fasteners or other parts. Some wrenches have jaws; others have sockets. Special hand wrenches may have openings to fit a fastener with an unusual head shape. Fasteners with special heads are often used when space problems mean that common tools cannot be used. Sometimes the wrench handle is specially shaped to fit where clearances are tight. **Figure 3-3** shows a wrench designed to fit a fastener having both an unusual head and a hard-to-access location.

Spanner wrenches, shown in **Figure 3-4**, are special service tools used to tighten large parts or to hold parts in place while other tools are used. Most spanner wrenches are one-piece units. Some spanner wrenches, like the one in **Figure 3-4A**, have lugs that fit into holes in the part. Others, like the spanner wrench shown in **Figure 3-4B**, have provisions for bolting to the parts they hold.



J 9522-3 cross remover



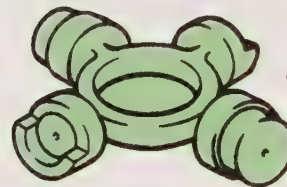
J 23498 drive shaft inclinometer



J 9522-5 spacer



J 35819 runout gauge



J 23498-20 drive shaft inclinometer adapter

Figure 3-1. Various special tools are used to service rear-wheel drive vehicle drive trains. (General Motors)

In addition to such wrenches, special sockets are available that have shapes or depths to fit fasteners that are different from standard or to fit where clearance is a problem. See **Figure 3-5**. These sockets are designed to fit standard handles and drive sizes, such as 3/8" or 1/2" ratchets and extensions. They are used the same way as any other socket.

Punches and Drifts

Punches and **drifts** are removal and installation tools designed to be struck with a hammer. They are used to remove pins, plugs, and other pressed-in parts from bores. The punch or drift is placed against the part to be removed. The top of the tool is struck with the hammer. A punch and a drift are included among tools shown in **Figure 3-6**. Note that drifts can be made from discarded steel or brass rods.

Manual Transaxles Special Service Tools

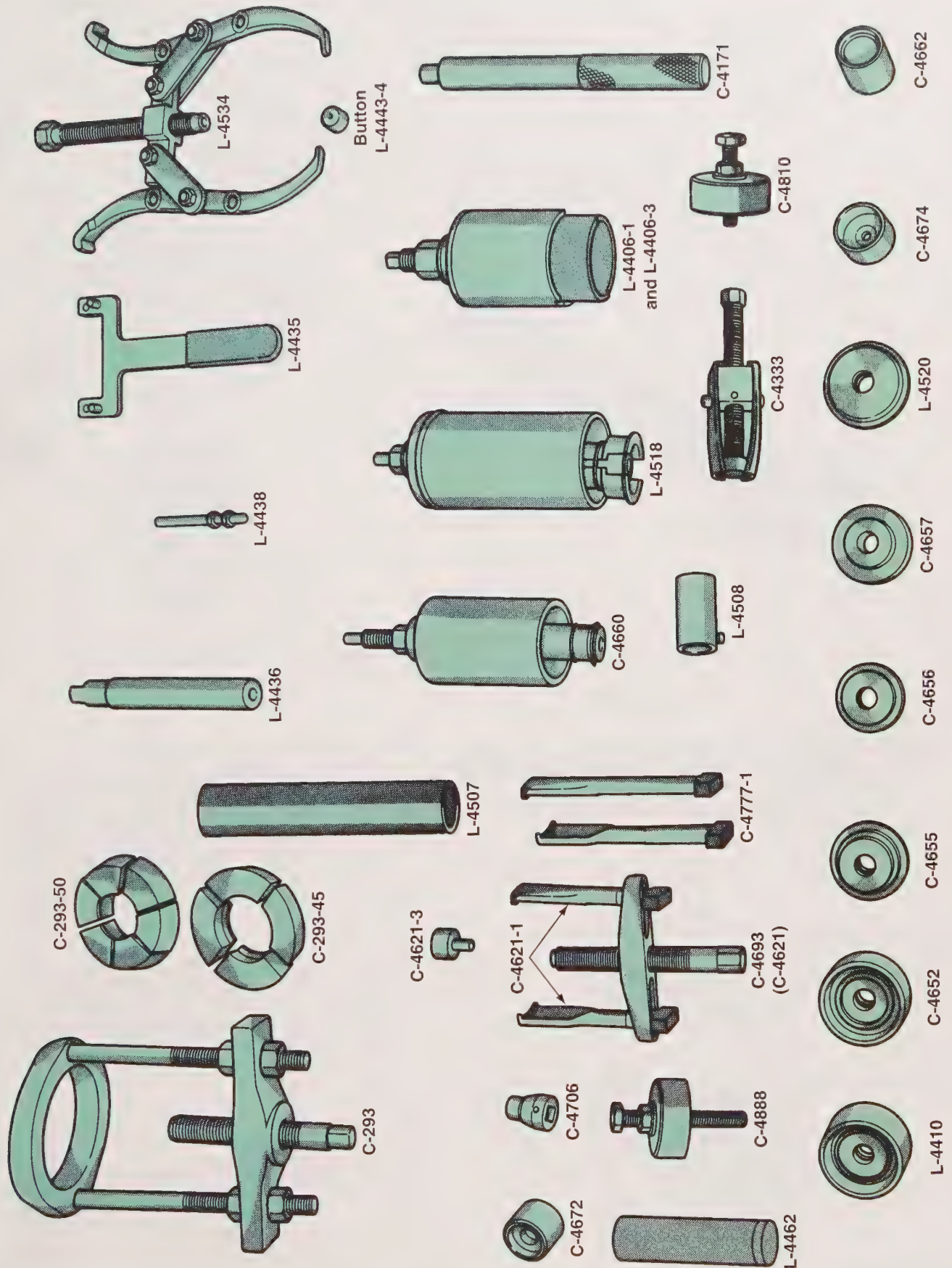


Figure 3-2. The tools shown here are used to repair the manual transaxle used on a common front-wheel drive vehicle. (Chrysler)

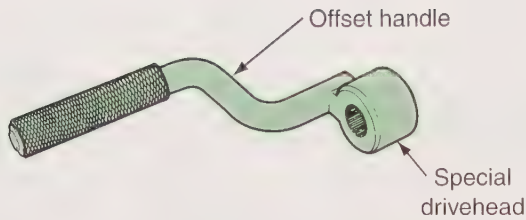


Figure 3-3. A hand wrench for servicing a transmission assembly. Notice the offset handle on this special wrench. The head is shaped to fit an unusual fastener.

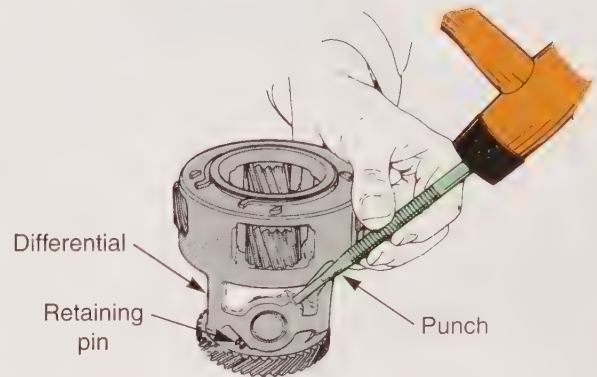
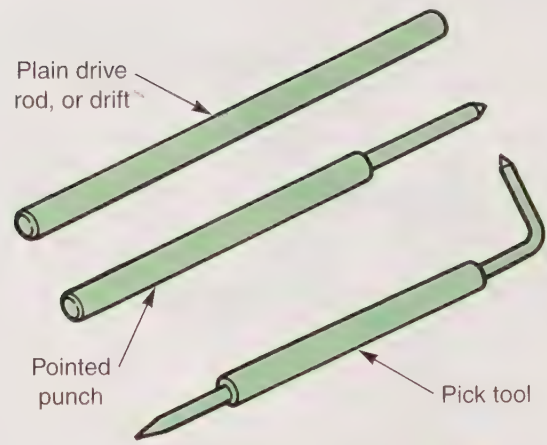


Figure 3-6. An assortment of special service tools. In this illustration, the pinion shaft retaining pin is being removed with a hammer and a punch. (General Motors)

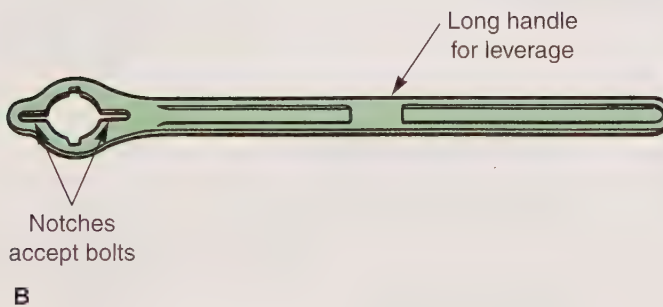
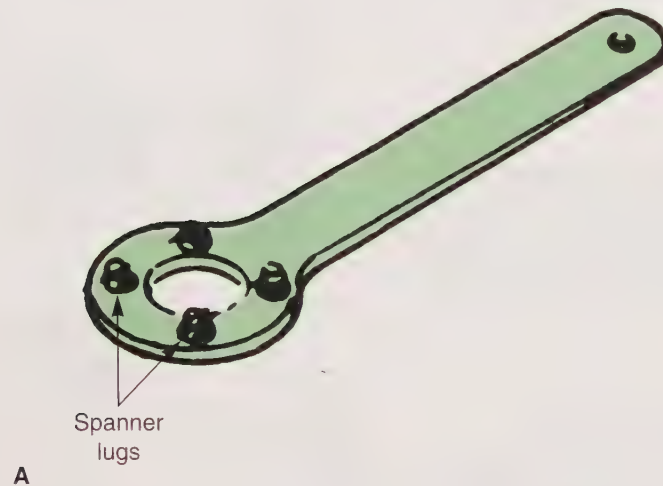


Figure 3-4. Spanner wrenches are used on certain parts of the drive train. A—This spanner wrench has special lugs that fit into holes in the drive pinion flange. B—This type of spanner wrench is bolted to the part on which it is used.

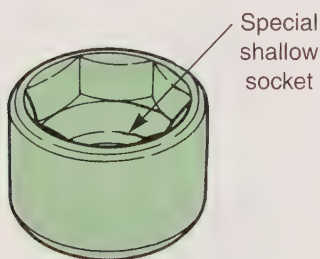


Figure 3-5. This special socket is made for a drive pinion locknut. A socket such as this is used when a standard socket will not fit because of clearance problems.

Snap Ring Pliers and Picks

Snap ring pliers are special service tools used for removing and installing snap rings or retainer rings. As pictured in **Figure 3-7**, snap ring pliers have special jaws that fit and grasp the snap ring. Note that eye protection should always be worn when working with snap rings. A flexed ring can shoot into your face with considerable force.

Picks may also be used for removing snap rings. Picks are pointed tools. (Refer back to **Figure 3-6**.) Ordinary ice picks are often used as picks. Picks are useful for prying on parts and for jobs requiring a small pointed tool. These tools can be used to get under, pry up, and remove snap rings when there is no other way of removing them.

Presses

In many cases, drive train parts are assembled using an **interference fit**. This means that one part was machined slightly larger than the space of the mating part into which it is fit. A shaft driven into a smaller hole is an example. The parts press together tightly and cannot be removed easily. A **press fit** is one type of interference fit. In this type of fit, considerable pressure is applied to the mating pieces to get them to fit together.

Often, gears and bearings have an interference fit with the shafts on which they ride. These parts can be easily

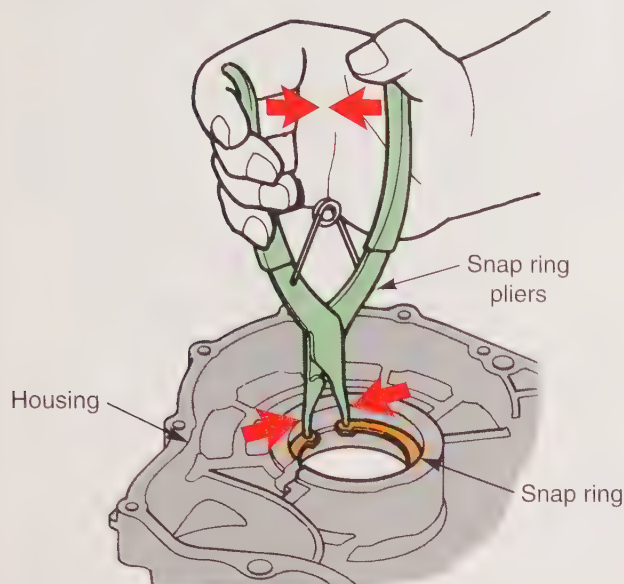


Figure 3-7. Snap ring pliers are designed for removing snap rings. The illustration shows a snap ring being installed in a transmission housing. (Honda)

removed from a shaft with a press. A **press** is a piece of equipment consisting essentially of a frame and a ram and is used for applying pressure on an assembly. Presses are also used for installing gears and bearings on a shaft.

The most common press found in repair shops today is the hydraulic press, **Figure 3-8**. This press has

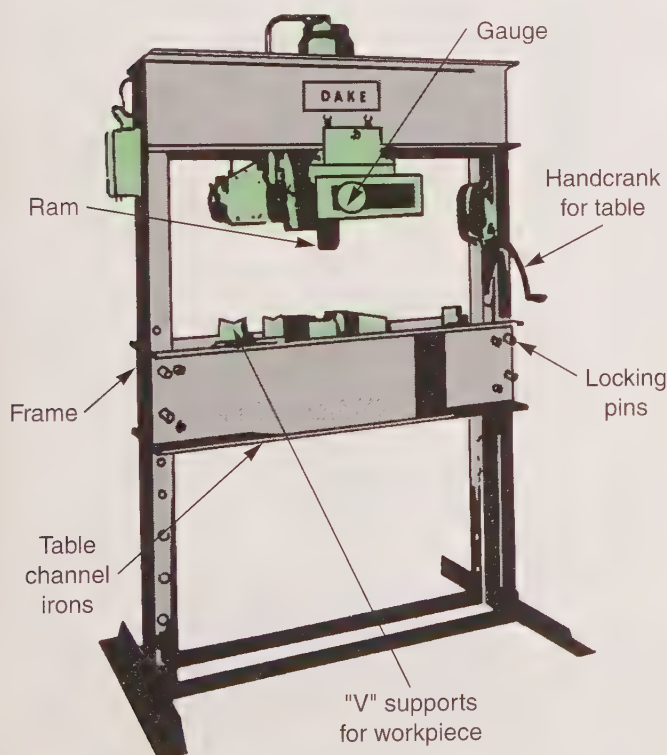


Figure 3-8. The hydraulic press is used to remove many pressed-on parts such as axle bearings and automatic transmission bushings. (Dake)

a hydraulic ram. Pressure is developed by a hand-operated piston or, on larger presses, by an electrically powered pump.

Special adapters are often used to make the pressing operation easier. The adapter shown in **Figure 3-9** is used for pulling bearings. The tool fits under the bearing. It provides a firm surface for the bearing to rest on. Adapters are usually adjustable. This permits use with many sizes of gears and bearings.

Another type of press is the mechanical arbor press. It is hand operated and is used for lighter-duty jobs. It performs the same function as a hydraulic press, but ram-pressure capability is much less.

Drivers

There are several different types of **drivers**. One type is used to install and remove bearings and seals in housings. This driver is driven by a hydraulic press or an arbor press. If a press is not available, a hammer can sometimes be used with the driver, **Figure 3-10**. When using either method, always wear eye protection. Also, ensure that the part is properly aligned in the bore.

Before using a driver, make sure it is the proper size for a particular job—that it exactly fits the seal or bearing to be installed or removed. The shape of the driver is critical. If the driver is not the proper size and shape, the part will be damaged. See **Figure 3-11**.

Figure 3-12 shows drivers being used to install and remove bushings, which are a type of bearing. In either case,

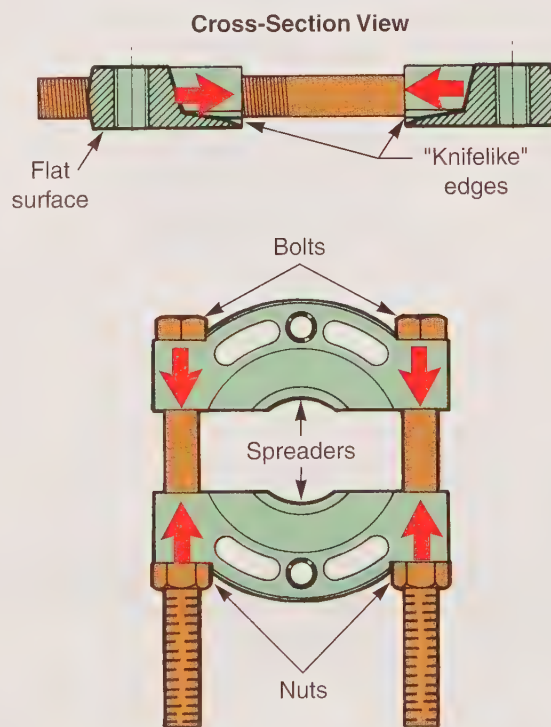


Figure 3-9. Bearing adapters are used to make bearing removal jobs easier and speed the process. The adapter is installed under the bearing.

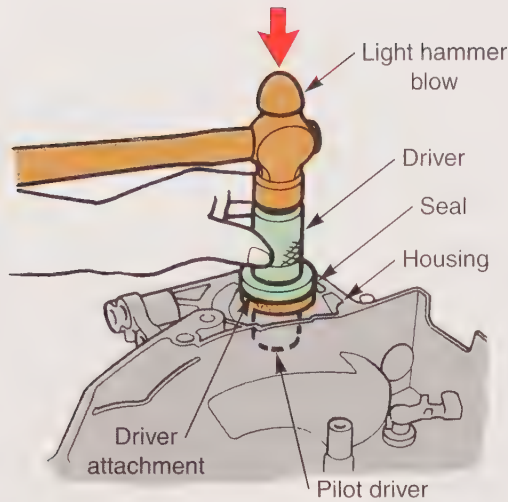


Figure 3-10. A hammer is used on a driver to install the oil seal in a torque converter housing. Note the pilot driver is used to ensure that the seal is driven in straight. It aligns the driver and attachment. (Honda)

the outside diameter of the driving surface should be slightly smaller than the bore diameter. This allows the driver to push the bushing into or out of a bore without contacting the bore itself. Drivers for bearings to be installed to specified depths have a shoulder larger than the housing bore, as shown in **Figure 3-12A**. The bushing is at the proper depth when the shoulder bottoms on the housing. **Figure 3-12B** shows a driver used for removing a bushing. For obvious reasons, this driver does not need or have such a shoulder.

Another type of driver is the C-frame driver, shown in **Figure 3-13**. This type is used for installing specific parts, such as ball joints. Proper adapters are selected before

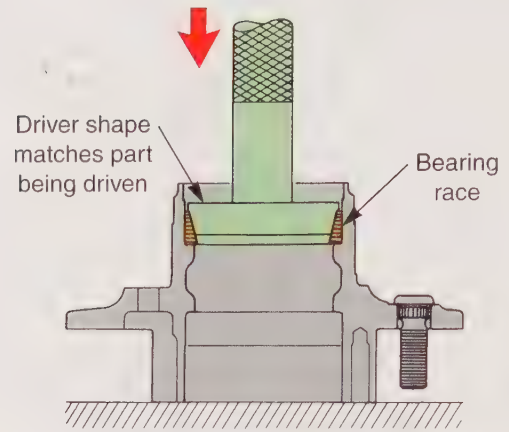


Figure 3-11. When installing a bearing race, check that the driver closely matches the inner shape of the race or damage may result. (Chrysler)

using the C-frame driver. The screw is then tightened to install the part.

Pullers

To remove parts that are pressed together, **pullers** are often used. A puller is a device that exerts pressure on such parts to separate them. There are many kinds of pullers.

Figure 3-14 shows some pullers you might use to remove drive train parts. A wheel puller, **Figure 3-14A**, is a tool that uses screw threads to exert pressure. It is used to remove gears, pulleys, or bearings from a central shaft. The puller bolts attach the screw and plate assembly to the part to be removed. The central screw is then tightened to pull the part from the shaft.

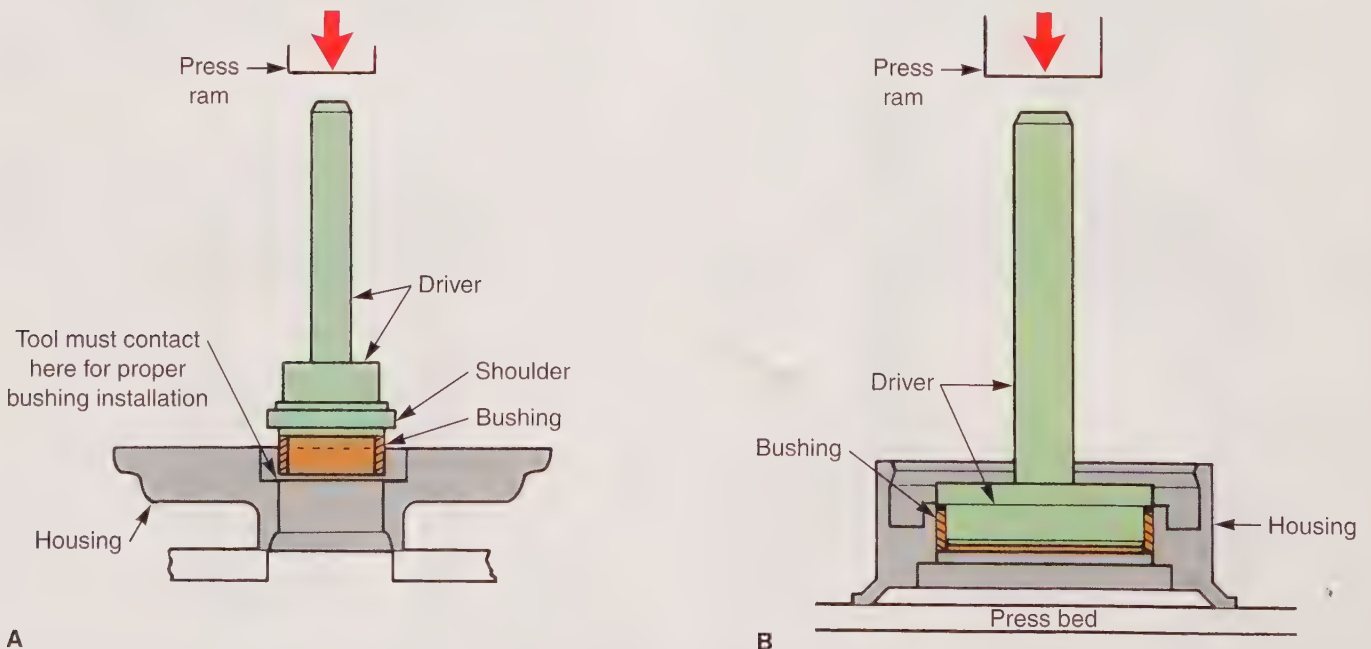


Figure 3-12. Make sure the driver diameter matches the part being installed. A—Driver being used with hydraulic press for installation of a pump bearing, or bushing. B—Driver being used with hydraulic press for removal of the forward clutch hub bushing. (Ford)

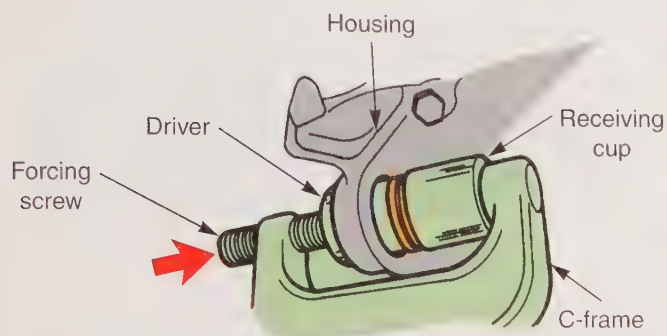
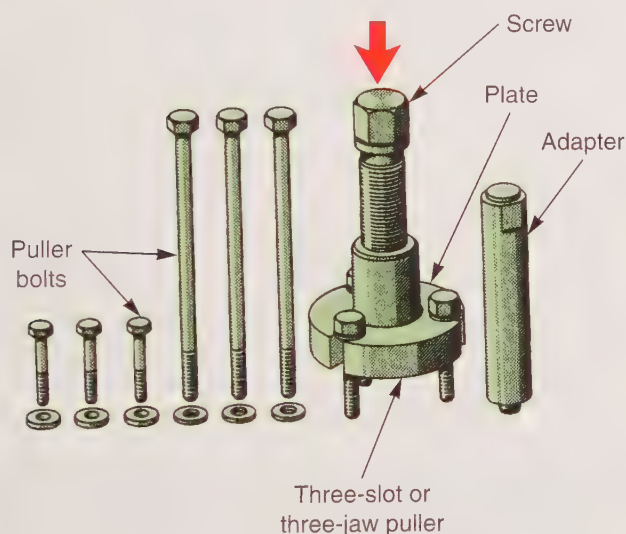
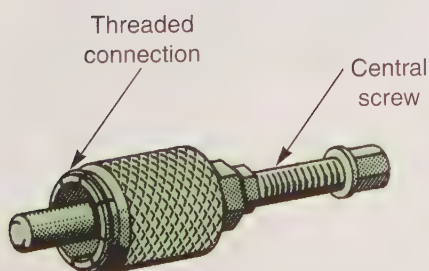


Figure 3-13. The C-frame driver is a special-purpose pressing tool. It is used in many places where a large force must be applied in a confined space. (Ford)

The operation of another type of puller, **Figure 3-14B**, is similar to that of the wheel puller. This kind of puller is usually used to remove seals or other parts that are lightly pressed in. The tool is fastened onto the part by the threaded connection. Tightening the central screw causes the part to be pulled out. One disadvantage of this puller is that threading the tool into the pressed-in part usually ruins the part.



A

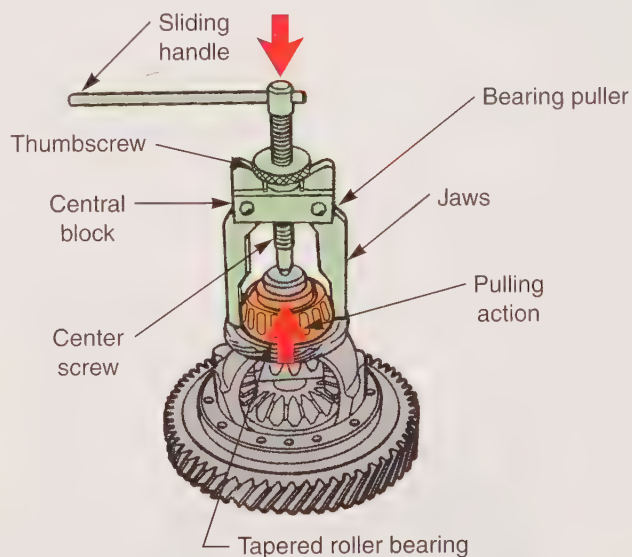


B

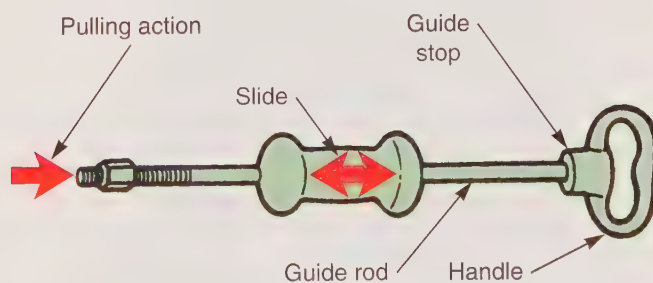
A jaw puller, also called a bearing puller, shown in **Figure 3-14C**, is a third kind of puller. A jaw puller is used to remove bearings from shafts or housings. It consists of a central block with a center screw and jaws that pivot from the block. The puller jaws are placed over the bearing to be removed. The jaws are securely tightened in place with bolts or a thumbscrew that draws the jaws in toward the center. The center screw is then tightened to pull the bearing from the shaft.

Another tool used to remove parts is the slide hammer, or impact puller, **Figure 3-14D**. Its pulling force comes from impact instead of screw force. The puller is installed on the part to be removed. This is sometimes done by threading the guide rod into an existing threaded hole on the part. Other times, an adapter, attached to the threaded end of the guide rod, is used. Then, the slide, which is weighted, is pulled sharply against the shoulder of the guide stop. The resulting impact is transmitted to the part, and the part is removed from its position.

To remove oil seals, a special adapter is sometimes used with the slide hammer. This adapter consists of a sheet metal screw that is brazed or welded onto a nut. The



C



D

Figure 3-14. Pullers are used to remove many components of the drive train. A—This kind of puller is used to remove pressed-on parts that have threaded holes to accept puller bolts. B—This puller threads into the part to be removed. The part is usually ruined in the pulling process. C—The jaw puller is used to remove many antifriction bearings. It must be carefully installed. D—The slide hammer can be used to remove many kinds of bearings and seals. This tool will accept any number of adapters. (Mercedes-Benz, Honda, Chrysler)

internal threads of the nut match the external threads of the slide hammer guide rod. To remove a seal, a small hole is drilled into the metal portion of the seal. The adapter screw is then threaded tightly into the hole. The guide rod is threaded into the adapter nut. After the adapter is attached to the guide rod, the slide portion of the slide hammer can be moved sharply against the shoulder of the guide stop to remove the seal. If the seal is difficult to remove or the hole becomes stripped, another hole can be drilled into the opposite side of the seal and the removal process can be repeated.

Special precautions should be taken when using pullers:

- ❑ Always wear eye protection. Failure to do so could result in irreversible eye damage.
- ❑ Always install the puller properly. An improperly installed puller could cause injury or damage.
- ❑ Never apply force through the rolling elements of a ball or roller bearing. The bearing will most likely be ruined, and it may fly apart causing additional damage and injury.

Seal Protectors

Seal protectors are metal or plastic sleeves. They are used to prevent seal damage when a seal is installed over a shaft with a sharp area such as a keyway, **Figure 3-15**. Once the seal is in place, the protector can be removed.

Alignment Tools

Alignment tools are used in clutch and transmission work. A clutch alignment tool, **Figure 3-16**, is used to keep

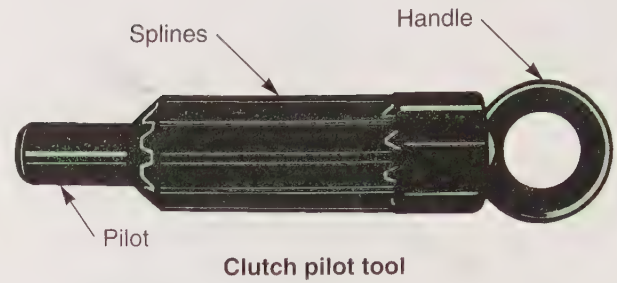


Figure 3-16. A clutch alignment tool holds the clutch disc in alignment as the pressure plate is tightened.

the clutch disc in alignment as the clutch cover attaching bolts are tightened. The tool is sometimes called a pilot shaft.

Transmission alignment tools are used to align some transmission internal parts during assembly. These parts are usually moving or are supports for moving parts. Types of transmission alignment tools will vary.

Flywheel Turning and Locking Tools

Often, the engine flywheel must be turned or held stationary so bolts that need to be loosened or tightened can be reached. **Flywheel turners** move the flywheel by engaging two or more teeth on the flywheel ring gear. The handle is long enough to provide good mechanical advantage, which enables the flywheel to be turned easily. See **Figure 3-17**.

A **flywheel holder** is used to keep the flywheel from turning. One end of the flywheel holder has teeth that engage the teeth on the flywheel ring gear. The other end of the tool is bolted to the engine block or to another stationary part of the drive train. See **Figure 3-18**.



Figure 3-15. Using seal protectors prevents damage when seals are installed over shafts. (Owatonna Tool)

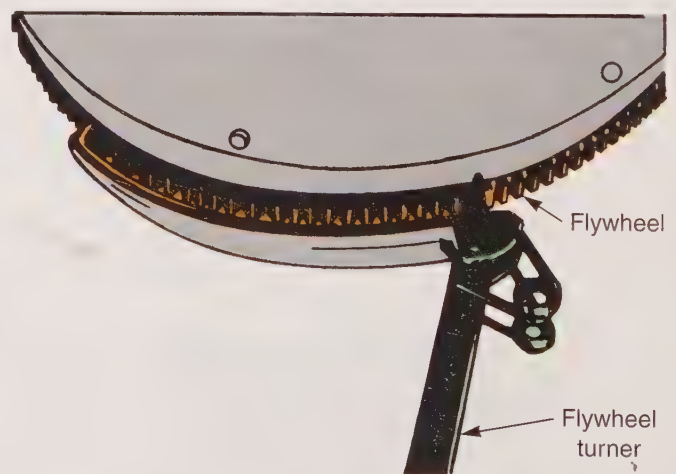


Figure 3-17. Flywheel turners are useful when the flywheel must be turned by small amounts, such as when converter or pressure plate bolts are being installed.

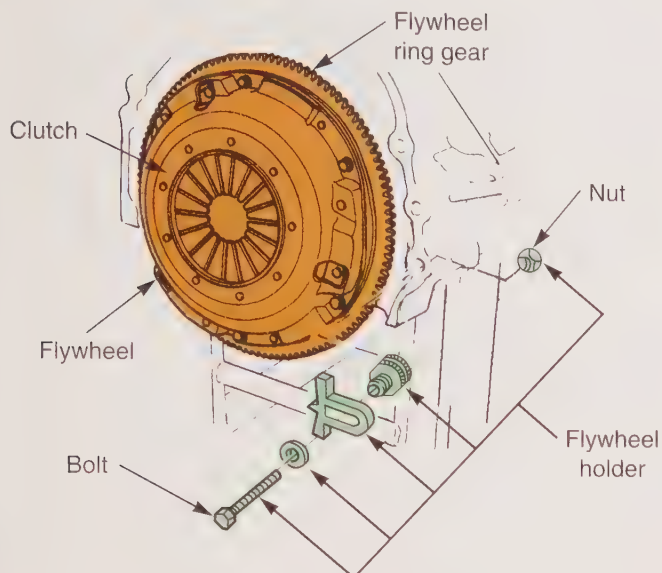


Figure 3-18. Flywheel holders are useful when the flywheel must be held stationary, such as when converter, flywheel, or pressure plate bolts are tightened or loosened. (Honda)

Drain Pans

If oil is allowed to drip on the floor during repairs, it will create a safety hazard. Further, if tracked onto carpets and other floor treatments, oil can cause damage. **Drain pans** are handy for catching oil that drips from assemblies as they are drained or disassembled, **Figure 3-19**.

Screw Extractors

Screw extractors are used to remove broken screws or other broken fasteners from parts. Screw extractors are hardened shafts designed to grip a broken fastener from the inside. To use this kind of extractor, drill a hole into the broken fastener. (This hole must be the proper size for the extractor to be used, and it must be exactly in the center of the fastener shaft.) Then, lightly tap the extractor into

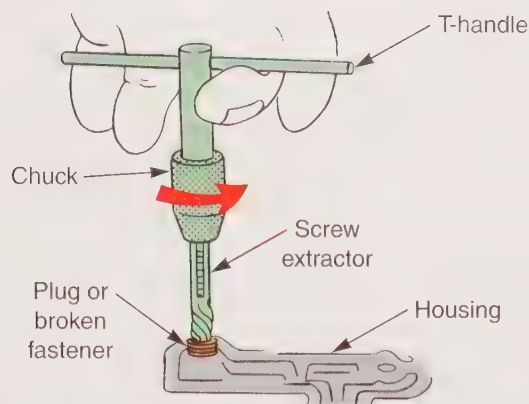


Figure 3-20. A screw extractor is used for removing broken fasteners from parts. A hole must be drilled in the fastener before the kind of extractor pictured can be used. (General Motors)

the hole, and back it out with a wrench. The fastener will unscrew in the process. This is shown in **Figure 3-20**.

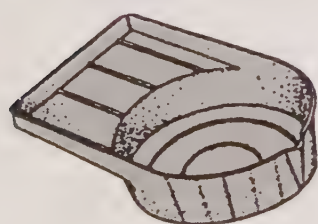
Other tools are available for extracting fasteners from parts. These are designed to grip the fastener from the outside. They can be used only if the broken fastener extends from the part. A special stud puller is an example. Sometimes vise grip pliers can be used for this purpose.

Drive Train Lifting and Holding Equipment

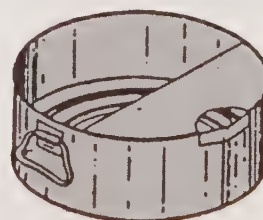
Most drive train components are large, heavy, and awkward. To assist in removing and servicing them, some special equipment is needed.

Holding fixtures

Holding fixtures are handy for holding large components such as transmissions, rear axle assemblies, and transaxles. Some holding fixtures can be used with only one type of component, while others can be used with any transmission or transaxle.



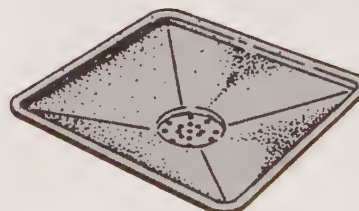
Large transmission service pan



Galvanized drive pan



Oil drain pan



Transmission fluid drain funnel under-hoist type

Figure 3-19. The drain pans shown here are useful for catching oil. This helps to prevent messes and accidents. (Hayden)

Transmission jacks

Transmissions and transaxles are large, heavy assemblies. They can cause serious injury if they are allowed to fall. Lifting them into place during installation can also pose problems. To prevent this, **transmission jacks** should be used to remove and install transmissions. See **Figure 3-21**.

Drive Train Cleaning Equipment

Drive train parts are located under the vehicle. As a result, they collect dirt from the road. The dirt mixes with leaking oil. Heavy grease deposits result. Internal drive train parts usually require cleaning because of the heavy oils used. Further, where there is internal damage, heavy debris and metal deposits will be present. For these reasons, special cleaning equipment is needed. Since some cleaning solutions, rust removers, and degreasers may contain hazardous chemicals, care must be taken when disposing of these cleaners. Different types of cleaning equipment are presented in the next few paragraphs, as well as a discussion on disposing of hazardous cleaning chemicals.

Parts washers

After you have removed all the parts from an assembly, everything should be cleaned. Problems can be hard to see when a part is covered with oil, grease, or dirt. Closer part inspection can be done during and after part cleaning. **Parts washers** are often used for cleaning. Different types are available, depending on the part construction and type of material. See **Figure 3-22**.

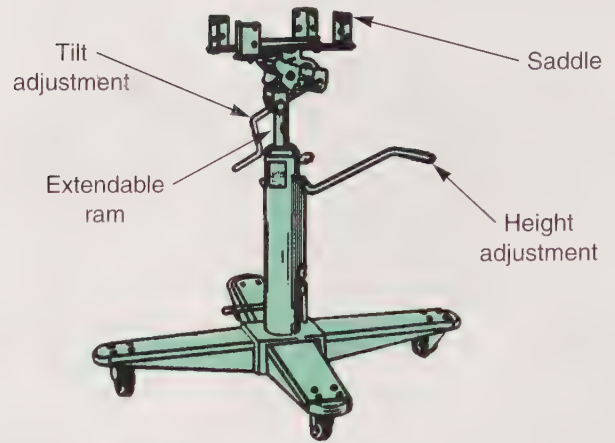


Figure 3-21. This transmission jack is designed to be used when the vehicle is on a hoist. (Hayden)

One type of parts washer is the cold-soak tank. It can be thought of as a sink that runs cleaning solvent instead of water. The solvent aids in dirt and grease removal. Most parts washers have a pump to circulate the solvent. Parts are left to soak in the solvent. When necessary, brushes and scrapers are used for cleaning. Since the solvent is much harsher than water, you should always protect your hands and face when using it.

Another more powerful kind of parts washer is called an immersion cleaner, or a hot tank. The part to be cleaned is placed in the tank, which usually is filled with strong corrosive chemicals. An automatic process cleans the part.

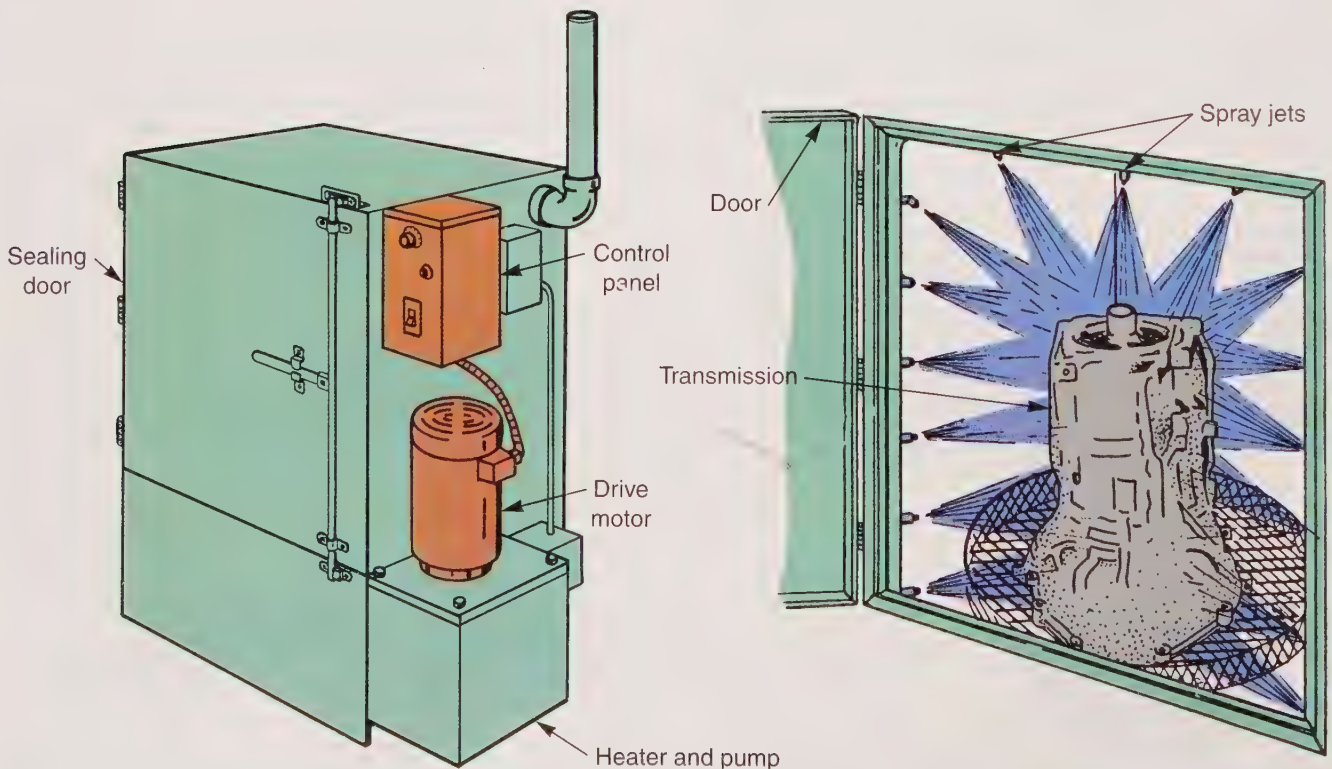


Figure 3-22. This parts washer will clean the interior and exterior of large parts with spray action. (Hayden)

Disposal of vehicle maintenance products

Certain products involved in vehicle maintenance, such as rust removers, parts cleaners, and degreasers, may contain hazardous materials. These products, for example, may contain toxic chemicals or strong acid or alkaline solutions and must be disposed of properly. Petroleum products used for vehicle operation, such as automatic transmission fluid and gear oil, are also examples of materials that require special handling. If you generate hazardous waste, you might be subject to regulations that govern the disposal of these waste products. In particular, any business that maintains or repairs vehicles, heavy equipment, or farm equipment is subject to the requirements of the Resource Conservation and Recovery Act. Check with your state's hazardous waste management agency or Regional EPA (Environmental Protection Agency) office for more information.

Drive Train Measuring Tools

Many drive train components require special measuring tools in the reassembly process and afterwards to ensure they have been put together correctly. **Gauges** are used for this purpose. A gauge is an instrument used to measure something. In drive train service, pressure gauges, size gauges, and angle gauges are often used. Another gauge commonly used measures torque. This gauge is an integral part of a torque wrench.

Size gauges

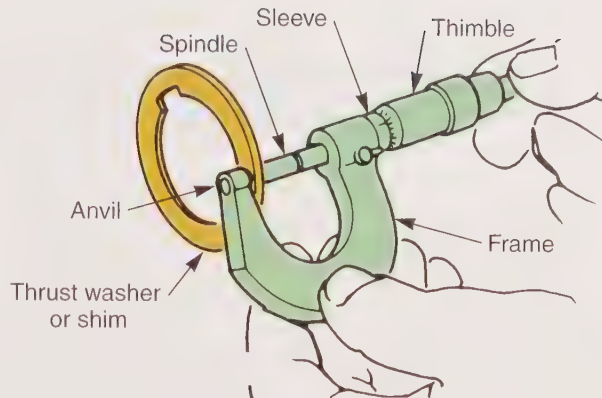
Size gauges are linear measurement devices. They are used for measuring part dimensions and clearances (the space between two parts). An example of one type of size gauge is the **micrometer**, or **mike**, shown in **Figure 3-23**. This type of gauge has a graduated scale from which very accurate measurements are read. Other size gauges give measurements by allowing you to choose the best fit from a set of gauges that range in size. A **feeler gauge** is used to measure spaces, or gaps, between two surfaces. A flat feeler gauge is made of a thin strip of steel or brass. A wire feeler gauge is made of a wire of specified diameter. Feeler gauges are usually sold in sets. A set will contain a number of gauges of different diameters or thicknesses. See **Figure 3-24**.

A feeler gauge is used by inserting it in the gap to be measured. Different thicknesses are tried. The correct gauge will drag slightly when pulled between the parts. The clearance, then, will be given by the size written on the gauge.

Size gauges are often used before assembly to determine what the clearances of mating parts will be after they are assembled. This eliminates the problem of assembling and reassembling parts to make adjustments.

Outside micrometers

In general, a **micrometer** is a measuring device that can make very accurate measurements. Refer to the **outside micrometer** pictured in **Figure 3-25**. Note that this



Part number	Thickness
90441-PL5-000	4.00 mm (0.157 in.)
90442-PL5-000	4.05 mm (0.159 in.)
90443-PL5-000	4.10 mm (0.161 in.)
90444-PL5-000	4.15 mm (0.163 in.)
90445-PL5-000	4.20 mm (0.165 in.)
90446-PL5-000	4.25 mm (0.167 in.)
90447-PL5-000	4.30 mm (0.169 in.)
90448-PL5-000	4.35 mm (0.171 in.)
90449-PL5-000	4.40 mm (0.173 in.)

Figure 3-23. The micrometer is used on machined parts to check that parts fall within tolerance. It is shown being used to check a thrust washer for proper thickness. (Honda)

micrometer has a frame, sleeve, thimble, spindle, and anvil. The opening between the anvil and spindle can be made larger or smaller by turning the thimble. The size of the opening can be read on the sleeve and thimble. Micrometers are available in inch-based and metric-based versions.

To use an outside micrometer, place the part to be measured between the anvil and spindle. **Figure 3-25** demonstrates this with a transmission thrust washer. Turn the



Figure 3-24. Flat and wire feeler gauges are useful for checking small clearances.

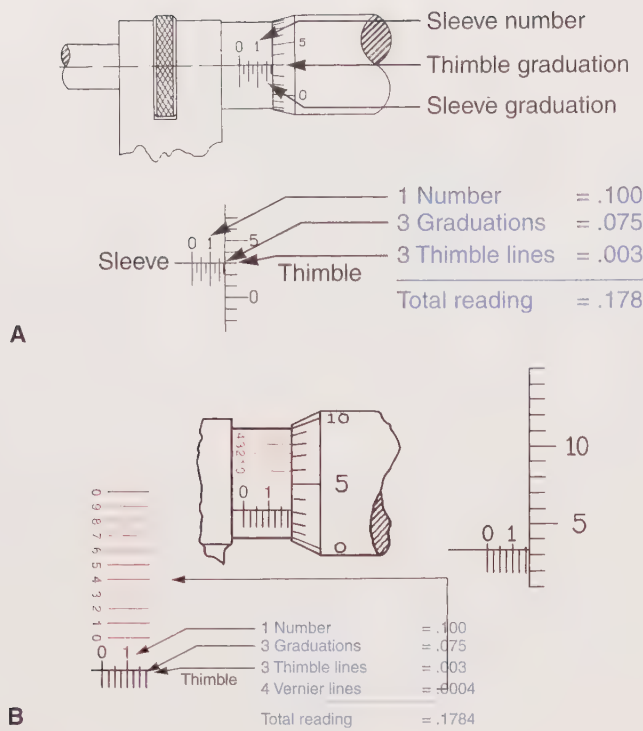


Figure 3-25. Reading a micrometer. **A**—Study the basic steps for reading a micrometer graduated in thousandths of an inch. Read the number, then the sleeve graduations, and then the thimble. Add these three values to obtain the reading. The total reading above is 0.178 inches. (Starrett) **B**—Vernier lines are shown in color. Note that vernier line No. 4 is the only one exactly in line with a thimble mark. Your reading would then be $.100 + .075 + .003 + .0004$ (four ten-thousandths) = .1784.

thimble to close the micrometer until it tightens lightly against the part. The part should move between the anvil and spindle with a light drag. Do *not* overtighten the micrometer. This will distort the frame and cause inaccurate readings.

The basic steps of reading a micrometer are similar for both inch-based and metric-based micrometers. To read an inch-based micrometer, set the part in place and read the greatest numbered division visible on the sleeve, **Figure 3-25A**. These numbers are in tenths of an inch (0.1"). Then, read the fractional increment visible on the sleeve. Each division is 25 thousandths of an inch (0.025"). Add these readings together and write them down. Then, read the number on the thimble that matches the centerline on the sleeve. Each division is 1 one-thousandth of an inch (0.001"). To obtain the final reading, add the sleeve and thimble readings together.

Note that a fourth decimal place is added to the final reading if there is an auxiliary scale, known as a vernier, on the sleeve of the micrometer, **Figure 3-25B**. This figure, which will be in 10 thousandths of an inch (0.010"), will be determined by the vernier line that exactly aligns with one of the lines on the thimble.

To read a metric-based micrometer, **Figure 3-26**, set the part in place and read the greatest division visible above the centerline of the sleeve. Each division is 1 millimeter.

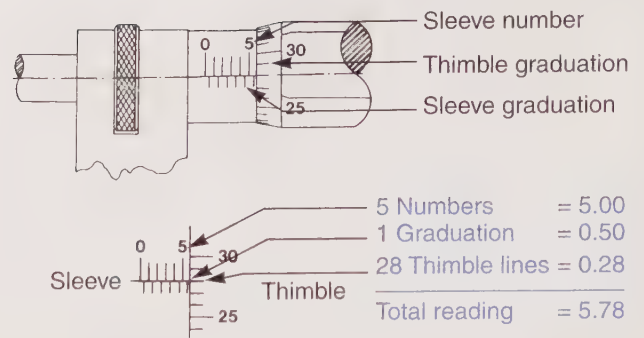


Figure 3-26. A metric micrometer is read like an inch-based micrometer. However, note the metric values for sleeve and thimble. Total reading above is 5.78 millimeters. (Starrett)

Add 0.5 millimeter if a following division mark is visible below the centerline. (On some micrometers, 1 mm divisions run below the centerline and 0.5 mm divisions run above.) Write down the number. Add this number to the number on the thimble that matches the centerline on the sleeve. Each division is 1 one-hundredth of a millimeter (0.01 mm).

Hole gauges and telescoping gauges

Hole gauges and **telescoping gauges**, shown in **Figure 3-27**, are used to make accurate measurements of the inside diameter of bushings and other internal surfaces. The hole gauge is used to measure small diameter holes or openings, **Figure 3-27A**. The gauge is inserted into the hole and adjusted to fit. Then, it is removed and measured with an outside micrometer. The telescoping gauge, **Figure 3-27B**, is generally used to measure larger openings. The gauge is placed in the hole, properly tightened, and locked. It is then withdrawn from the hole and measured with a micrometer. The micrometer reading is the size of the opening.

Inside micrometers

An **inside micrometer** is used for measuring larger inside diameters or other part openings, **Figure 3-28**. The instrument is placed within the bore or other opening and adjusted to fit. It is read in the same manner as an outside micrometer.

Depth micrometers

A **depth micrometer** is similar to the outside micrometer, but it is used to measure the depth of openings in machined surfaces. **Figure 3-29** shows a depth micrometer being used to check the depth of a bearing bore in a transmission case.

Calipers

Instruments called **calipers** make up a whole class of tools used for external or internal measurements. Outside and inside calipers are essentially a pair of movable legs,

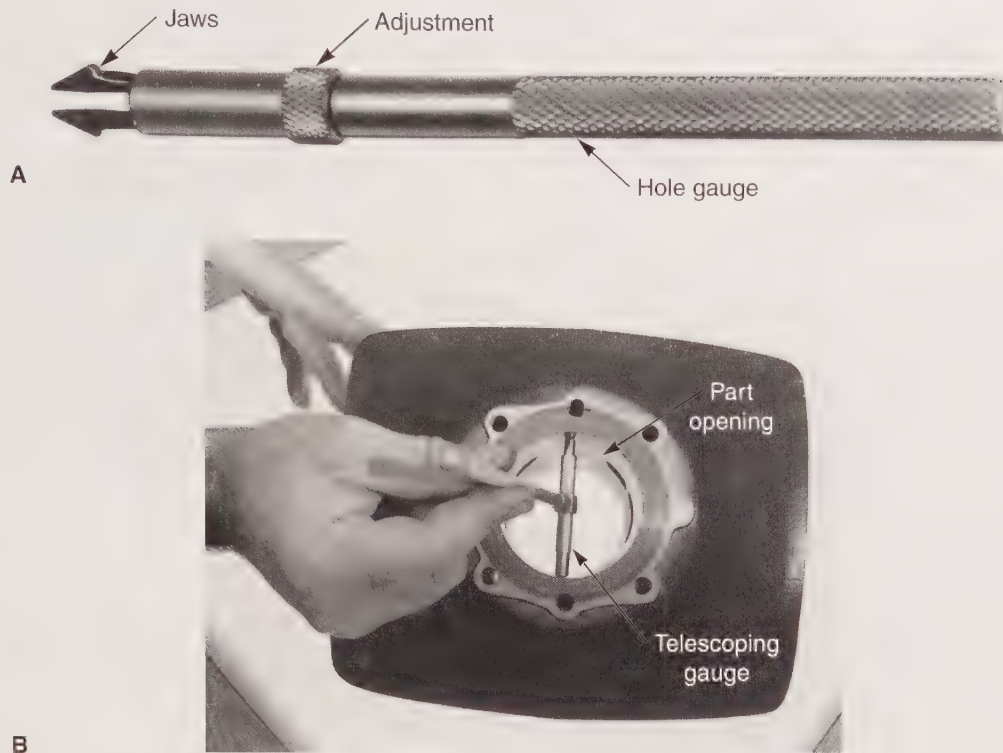


Figure 3-27. Tools used to measure diameters of small holes and openings. A—Hole gauge. B—Telescoping gauge. (Vaco)

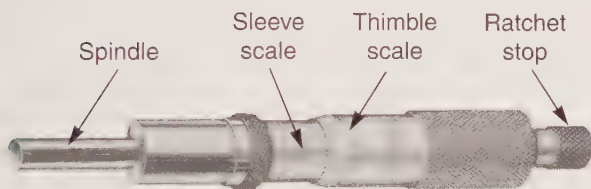


Figure 3-28. Inside micrometers measure larger holes and openings. (Starrett)

Figure 3-30. In measuring, the legs are adjusted to fit the dimension in question. The caliper can then be laid over a rule, and the span can be measured. Calipers of this type are less accurate than micrometers.

The vernier caliper is a type of sliding caliper. It is an accurate tool often used for measuring inside and outside diameters. This device is a ruled instrument that has a set of jaws, one fixed and one movable. The movable jaw has a sliding scale, or vernier. A component is placed within the jaws, and the movable jaw is adjusted to fit. The

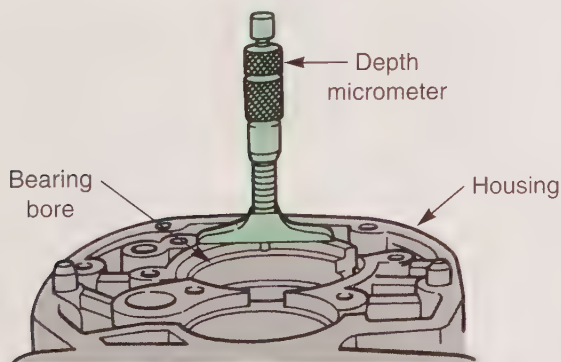


Figure 3-29. The depth micrometer measures the depth of bores and depressions in machined parts. The graduated scale (not shown) of the depth micrometer is read in the same manner as the outside micrometer. (Ford)



Figure 3-30. Outside and inside calipers used for making rough measurements on part openings. (Starrett)

sliding scale moves with the adjustable jaw since they are a unit. **Figure 3-31** shows a typical use of a vernier caliper. Note that the caliper shown has an additional set of jaws for making inside measurements.

Vernier calipers come in inch-based and metric-based versions. Readings can be obtained to 0.001" and 0.02 mm, respectively. Both types are read in more or less the same way. The measurement marked by 0 on the vernier scale is read from the fixed scale. To this measurement, the amount on the vernier is added. This amount is read from the vernier line that coincides with a line on the fixed scale. Only one vernier line will line up exactly with a line on the fixed scale.

A dial caliper is another type of sliding caliper. On this type of measuring tool, a dial gauge replaces the vernier. Otherwise, the two instruments look and operate the same. The dial gauge reads directly to 0.001" or 0.02 mm and makes precision measurements easier to read. Both vernier and dial calipers can be used and read quickly.

Straightedges, **Figure 3-32**, are used to check for warping of part surfaces. These hardened-steel bars are manufactured so that one edge is very straight. They serve as the standard against which to compare. The tool is placed directly on the part to be checked, and the part surface is checked in relation to the straightedge. If a feeler gauge over a certain size can be inserted between the part and straightedge, the part is excessively warped.

Dial indicators

A **dial indicator** is a gauge that is used on moving drive train parts to measure small amounts of movement. These instruments are frequently used to check gear backlash, or clearance between teeth, shaft endplay, cam lobe lift, and other similar kinds of part movements. The gauge, which has a dial face, is operated by a plunger. Typical

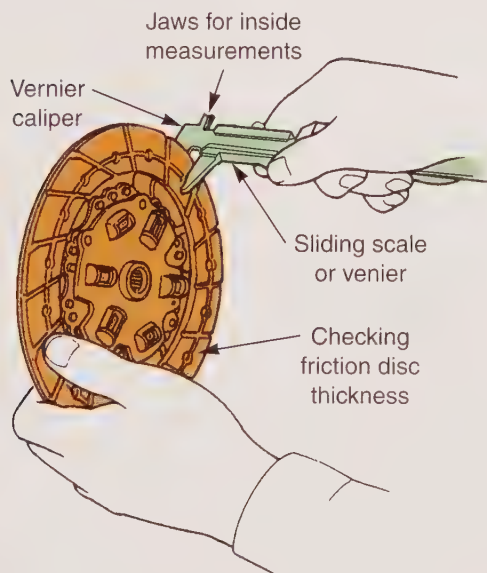


Figure 3-31. A vernier caliper being used to check the thickness of a clutch disc. (Honda)

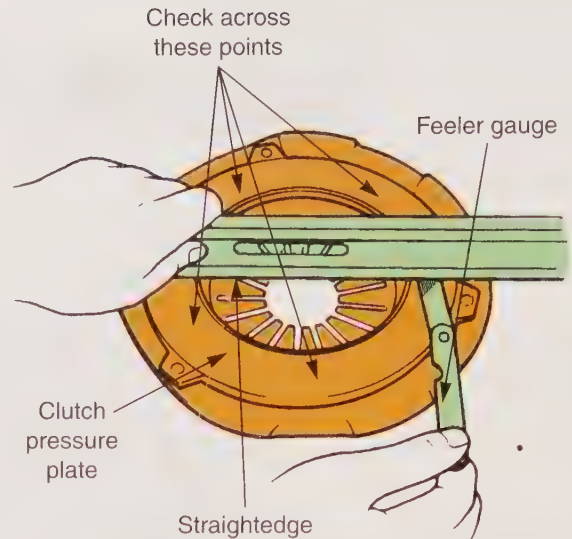


Figure 3-32. Straightedges are used in combination with feeler gauges to check surfaces for flatness. The straightedge is placed on the part, and various feeler gauges are inserted. If too large a feeler gauge can be inserted, the part is excessively warped.

scale graduations are in thousandths of an inch or hundredths of a millimeter, but finer divisions are available. The gauge can be zeroed (adjusted to zero) by turning the dial face assembly.

The dial indicator is mounted on or near the component to be checked. The contact point, or plunger, is positioned so that it contacts the movable portion of the component with a slight pressure. The gauge assembly should be secured so that only the plunger can move. Once the gauge is firmly in place, it should be zeroed. This is done by turning the dial face. The movable portion of the component is then moved back-and-forth or rotated, and a movement amount will be indicated on the dial face, **Figure 3-33**.

Angle gauges

Angle gauges are special devices that measure angles between two components or inclinations (angles relative to a plane of reference). Typically, they are used on driveline and drive axle components to determine the angles between them. This is done to correctly set angles for universal joints; otherwise, if an angle is too sharp, speed fluctuations and vibration problems can occur. The inclinometer, **Figure 3-34**, is an example of an angle gauge.

Torque wrenches

A **torque wrench** is a combination wrench and measuring device. It is used to apply a measured turning force, or torque, to a threaded fastener. The amount of torque is indicated on the tool while the force is applied, **Figure 3-35**. Torque wrench scales usually read in foot pounds (ft lbs) or in metric units of Newton-meters (N•m).

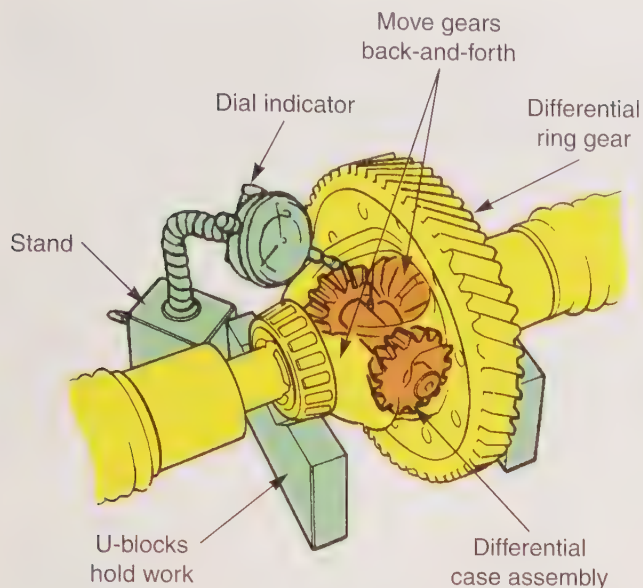
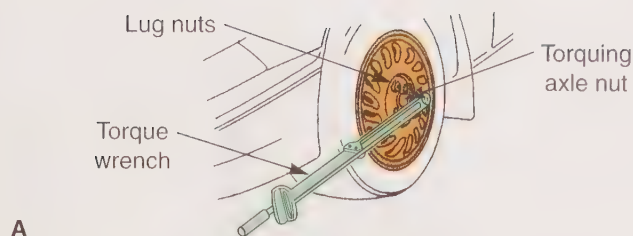


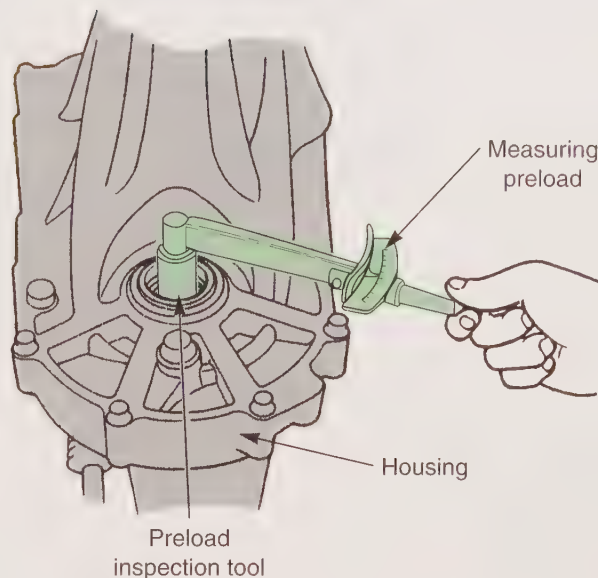
Figure 3-33. This dial indicator is being used to check a drive train assembly for improper clearance. If the dial indicator is installed and adjusted properly, the part can be checked to a thousandth of an inch or better. (Honda)

In **Figure 3-35A**, the torque wrench is used to tighten lug nuts to a specified value. When the proper value is read on the scale, the nut is as tight as it should be. In **Figure 3-35B**, the wrench is used to verify the amount of **preload** (mild pressure) on an installed bearing. In this procedure, enough torque is applied to the tightened fastener to cause it to move. Reading the scale at this point will give the torque on the bolt, which equates to the amount of preload on the bearing.

Every threaded fastener has a torque value. Some parts of the vehicle, such as the engine and drive train, require very precise torquing procedures. These procedures and torque values are given in the vehicle service manual. If the



A



B

Figure 3-35. Torque wrenches shown in two different applications. A—The wrench is being used to tighten a fastener to the proper torque value. B—The torque wrench is being used to check a bearing for the amount of preload to determine if it is properly adjusted. (Honda)

specifications are not available, standard torque references must be used to determine the proper torque, **Figure 3-36**.

Electrical and Electronic Testers

As recently as fifteen years ago, the drive train technician had no need to understand electrical or electronic theory. Today, however, an on-board computer may receive inputs from sensors installed on the drive train. This means that the drive train technician must have a basic knowledge of electrical and electronic theory, as well as a basic knowledge of some electrical and electronic test equipment. The following electrical testers are necessary to diagnose and service modern drive trains.

Jumper Wires

A **jumper wire**, or **jumper**, is a short piece of insulated wire with an alligator clip on each end. It is commonly used to bypass components and to apply voltage to a component or section of a circuit. It may be used to determine whether current is flowing through a switch, relay, solenoid,

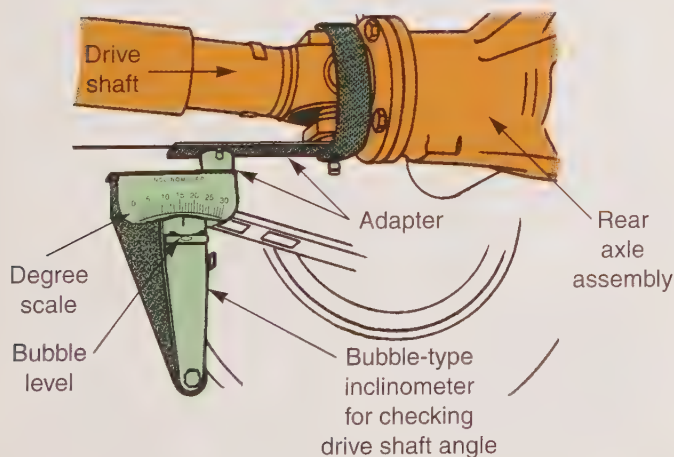
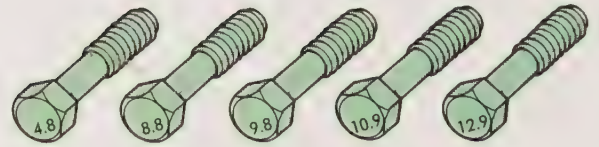


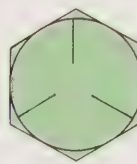
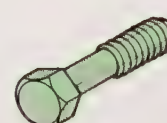
Figure 3-34. An inclinometer is used here to check the drive shaft angle. Note that several types of inclinometers are made. (General Motors)

Bolt size	Bolt Torque			
	Grade 5		Grade 8	
	N•m	ft lb (in lb)	N•m	ft lb (in lb)
1/4-20	11	(95)	14	(125)
1/4-28	11	(95)	17	(150)
5/16-18	23	(200)	31	(270)
5/16-24	27	20	34	25
3/8-16	41	30	54	40
3/8-24	48	35	61	45
7/16-14	68	50	88	65
7/16-20	75	55	95	70
1/2-13	102	75	136	100
1/2-20	115	85	149	110
9/16-12	142	105	183	135
9/16-18	156	115	203	150
5/8-11	203	150	264	195
5/8-18	217	160	285	210
3/4-16	237	175	305	225



Metric bolts—identification class numbers correspond to bolt strength—increasing numbers represent increasing strength

C

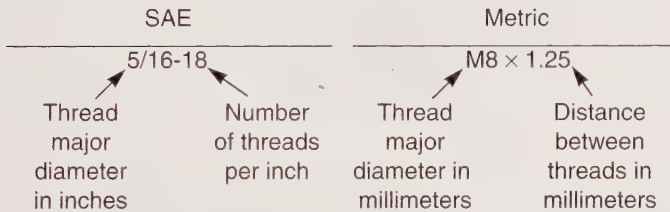
SAE Classification		
Grade 5		Grade 8
	Markings found on top of bolt head indicate grade	
120°		60°
		
Grade 2	Grade 5	Grade 8

(SAE) bolts—identification marks correspond to bolt strength—increasing numbers represent increasing strength

D

Figure 3-36. Torque references should be consulted when the torque requirement of a particular bolt is unknown. A—This table shows the maximum torque values for various sizes and grades of threads. B—This reference explains how to interpret SAE (inch) and metric thread notations. C—Strength of metric bolts may be determined by the identification class number on the head of the bolt. D—Strength of SAE bolts may be determined by the identification markings embossed on the bolt head. (Chrysler)

A



B

electrical connection, wire, or other electrical component. Jumper wires should be equipped with a fuse or circuit breaker to reduce the chance of damaging a circuit.

Figure 3-37 shows how a jumper wire is used to check a switch. Prior to bypassing the switch with the jumper wire, the bulb would not light when the switch was in the “on” position (contacts should have been made, or closed). If attaching the jumper around the switch turns the light on, then the switch is bad. If it does not, the problem is elsewhere in the circuit.

Test Lights

Test lights are often used to check whether electricity is reaching a particular point in an electrical circuit or to detect a circuit that is not allowing current to flow. The non-powered test light, **Figure 3-38**, can be used to probe

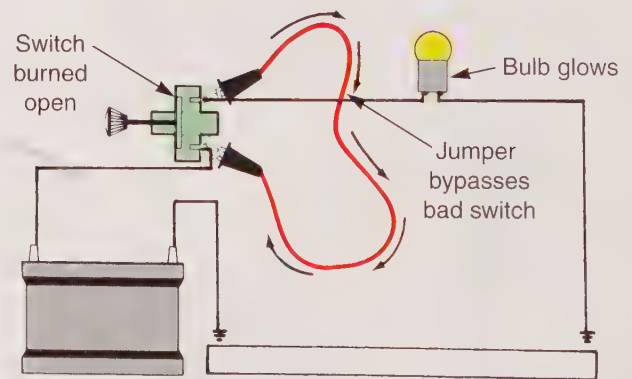


Figure 3-37. A jumper wire can be used for diagnosis. In this example, the wire is connected across the terminals of a switch that may be defective. If the light now comes on, the bypassed switch is the problem.

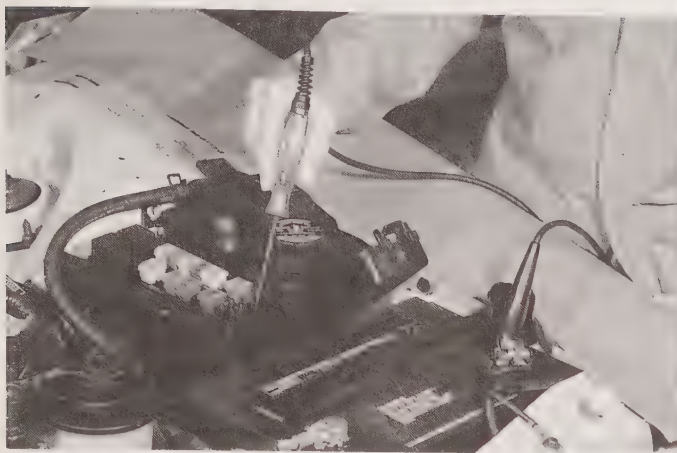


Figure 3-38. Twelve-volt non-powered test light. The sharp probe fits easily into small areas. Never pierce wire insulation unless recommended by the manufacturer.

electrical circuits to determine whether voltage is present. The battery-powered test light, **Figure 3-39**, is used to determine whether a circuit is complete. Test lights are useful when working on various parts of the electronic control system, but they must be used carefully or delicate electronic circuits will be damaged.

Multimeters

Multimeters are combination meters capable of measuring ohms, volts, and amps. Some are capable of displaying waveforms. A typical multimeter is shown in **Figure 3-40**. The multimeter is used when exact electrical values must be determined. Typical uses for a multimeter include checking for high resistance in an electrical connection, locating small battery drains, checking the resistance of sensors, and determining the condition of various electrical switches and solenoids.

Waveform Meters

The waveform created by the operation of some electrical and electronic devices can be observed to obtain

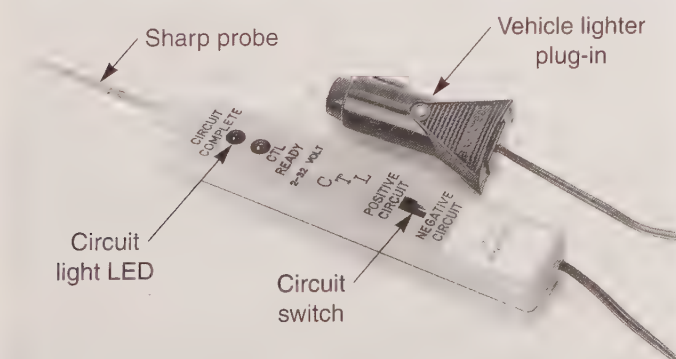


Figure 3-39. Powered test light. When the circuit is complete, the light will come on. (OTC Tools)

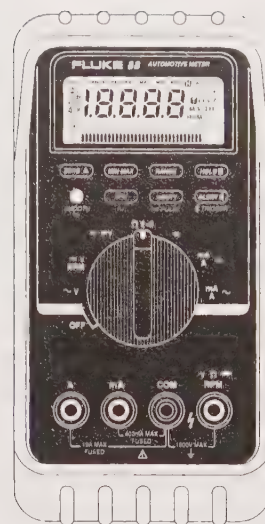


Figure 3-40. A typical multimeter. Handle with care. (Fluke)

various types of diagnostic information. Some multimeters can display waveforms. Another device for displaying waveforms is a lab scope, which some shops may have.

A typical waveform is shown in **Figure 3-41**. This waveform shows a solenoid being energized (turned on) and then de-energized (turned off). **Waveform meters** may be part of a multimeter, or they may be separate units. The advantage of waveforms is that they can indicate a problem more accurately than just voltage or resistance readings. For instance, the solenoid waveform shown in **Figure 3-42** is not shaped exactly like the standard waveform in **Figure 3-41**. Note the slope during the solenoid "on time" signal. This slope could indicate a problem in the solenoid windings or connections.

Scan Tools

Many transmissions, transaxles, and transfer cases are electronically controlled or have sensors that communicate

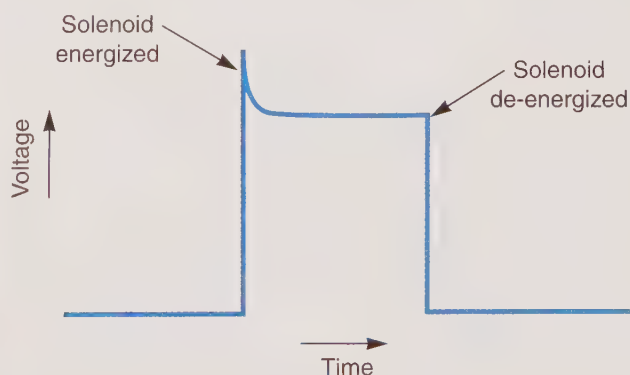


Figure 3-41. This illustration is a general representation of a waveform that occurs during normal operation of a transmission solenoid. The voltage is at zero until the solenoid is energized. The voltage rises sharply when the solenoid is energized. It then drops slightly once the solenoid plunger is pulled in, and then stays at this level until the solenoid is de-energized.

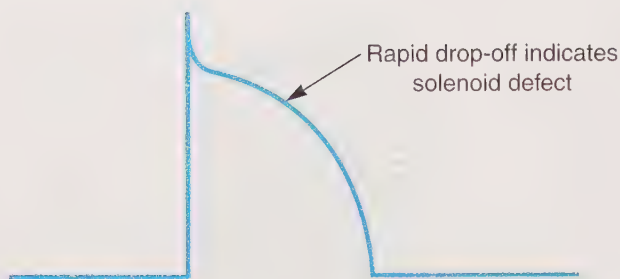


Figure 3-42. Compare this waveform with the waveform shown in Figure 3-41. The voltage rises when the solenoid is energized, but then drops off before the solenoid is de-energized. The drop may indicate that the solenoid winding is shorted or that it is drawing excessive current. It may also indicate a problem with the computer solenoid driver. This type of problem would not be caught if the voltage were simply checked with a voltmeter.

information to the on-board computer. The **scan tool** is used to check the operation of these electronic devices. The scan tool is attached to a diagnostic connector on the vehicle. This connector is usually the same connector used to retrieve engine information. Connecting the scan tool accesses the computer's self-diagnostic system. The scan tool retrieves trouble codes stored in the body of the computer. These trouble codes are stored when a system malfunction occurs. Retrieving these codes before performing other diagnostic steps makes the troubleshooting process quicker and easier. Modern scan tools can also perform other diagnostic tasks such as reading sensor outputs and measuring engine and vehicle speed. Scan tools also can be used to operate parts of the control system, such as pumps and solenoids, and to check system condition. **Figure 3-43** shows a typical scan tool.



Figure 3-43. One particular scan tool. Scan tools can be used to retrieve trouble codes and to check the operation of computer system components.



Caution: Older systems used a simpler self-diagnostic system now called **OBD I** (On-Board-Diagnostics I). Most **OBD I** systems were specific to the vehicle they were installed on. The improved **OBD II** system is standard to all newer vehicles. You *must* have the proper scan tool to access either of these systems.

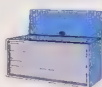
Protective Covers and Mats

No matter how well a vehicle is diagnosed and repaired, the customer will dissatisfied if it is returned damaged. Customers will quickly notice any scratches, dents, torn or dirty upholstery, or damaged trim. Always use **fender covers** to reduce the chance of damage to fenders from tools and belt buckles. Before placing a fender cover over any part of the vehicle, make sure that the underside of the cover is free of grease or dirt. Remove fender covers by lifting them from the body instead of sliding them off.

Before entering a vehicle, place a paper floor mat over the drivers' side carpet. This will catch any grease or dirt on your shoes. Install a **steering wheel cover** to reduce the chance of getting grease on the steering wheel. If there is any possibility of dirtying the vehicle's upholstery, place a protective **seat cover** on the drivers's seat.

Service Literature

Although it is seldom thought of as such, **service literature** is a tool. The service literature provides the specifications and the step-by-step instructions to properly service a particular vehicle. Often the vehicle drive train has been updated between two model years. Service literature simplifies the technician's job.



Note: Much of the service literature described below is available on **CD-ROM** discs. These discs can be inserted in a computer equipped with a **CD-ROM** drive. The information is then accessed and read on the computer screen.

Manufacturers' Service Manuals

Manufacturers' service manuals contain the information needed to repair transmissions and transaxles. They contain information that is specific to one vehicle make or model. Manufacturers' service manuals are divided into diagnosis and overhaul manuals.

Diagnosis manuals

Many vehicle manufacturers and some after market suppliers publish separate **diagnosis manuals**. These manuals contain only the information needed to diagnose problems. The diagnosis manual consists of troubleshooting

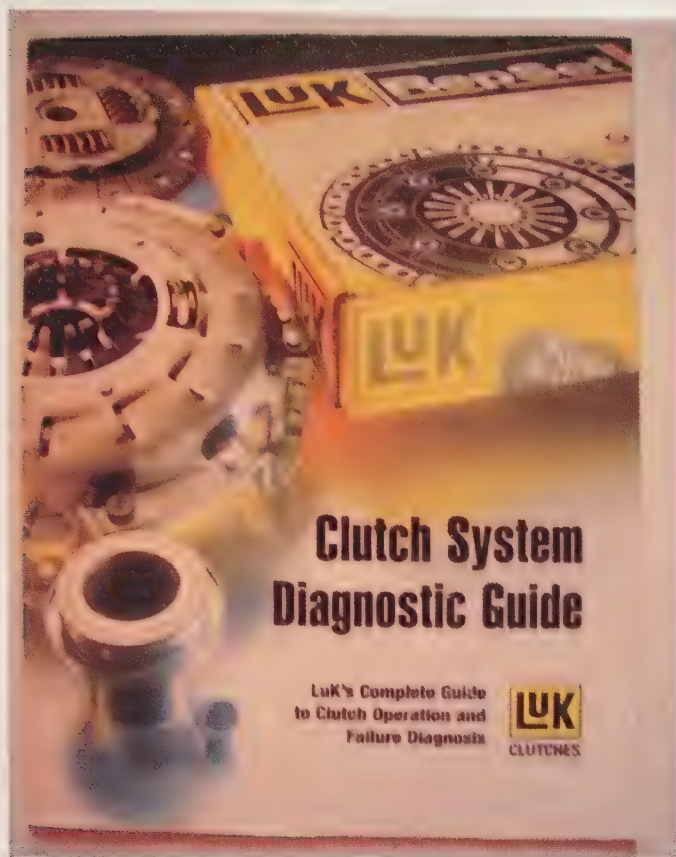


Figure 3-44. This diagnostic guide covers clutch operation and diagnosis.

procedures and discussion of common problems. Diagnosis manuals may also contain scan tool data and other specifications. A typical diagnosis manual is shown in **Figure 3-44**.

Overhaul manuals

Repair of component parts is covered in the overhaul manual. **Overhaul manuals** contain comprehensive information needed to disassemble, inspect, and reassemble vehicle components. A typical overhaul manual is shown in **Figure 3-45**. This information is confined to only disassembly and reassembly and does not cover transmission and transaxle diagnosis.

General Service Manuals

General service manuals provide broader coverage than manufacturers' manuals. They contain service information for many types of vehicles. Motor, Chilton, and Mitchell are among those publishing general service manuals. Like manufacturers' manuals, these manuals may be available in diagnosis, overhaul, and other variations. Many general manual publishers have separate transmission and transaxle manuals.

Schematics

It is almost impossible to repair modern vehicles without occasionally referring to a schematic. A **schematic**

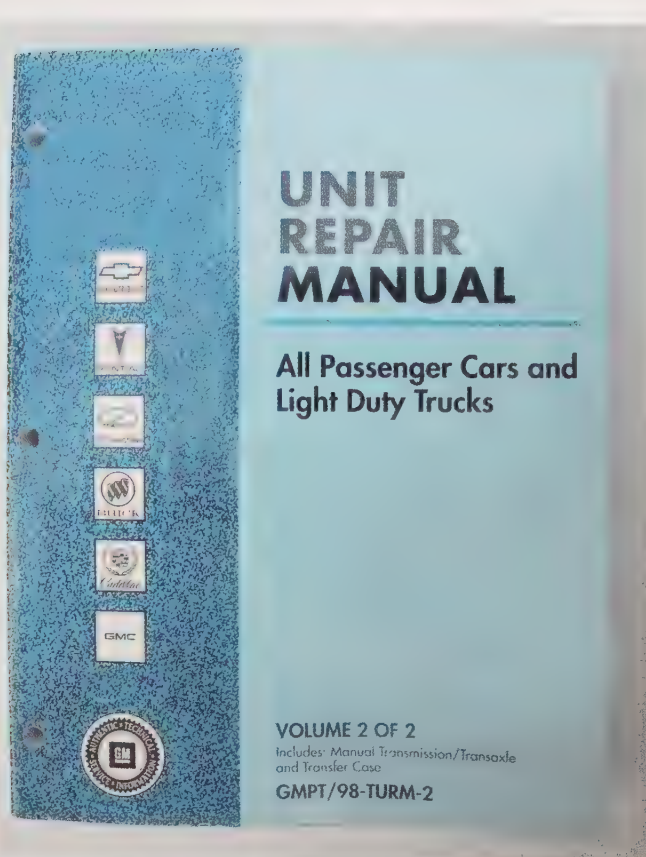


Figure 3-45. A typical transmission/transaxle overhaul manual. This manual contains information on how to disassemble and reassemble the transmission or transaxle and how to service its internal parts. The overhaul manual contains clearance, fastener torque, and other repair information, but does not include diagnostic information.

is a graphic representation of a hydraulic, pneumatic, or electrical system. By tracing the flow of power along the path shown in the schematic, the technician knows which components should be energized and under what conditions. A typical electrical schematic is shown in **Figure 3-46**. Appendix A lists some common symbols widely used in automotive electrical diagrams.

Troubleshooting Charts

Troubleshooting charts contain the logical steps used to proceed to the cause of a problem. A typical troubleshooting chart is shown in **Figure 3-47**. To use a troubleshooting chart, begin at the top and follow the instructions. In most cases, the chart will call for a yes or no answer at certain points. Depending on your answer, you will be directed to further diagnostic steps. If you follow the chart closely, you will reach the proper diagnosis.

Telephone Hotlines

If all other sources of information are exhausted, many technicians call a manufacturer's or part supplier's **telephone hotline**. Some general service manual manufacturers provide technical support services over a

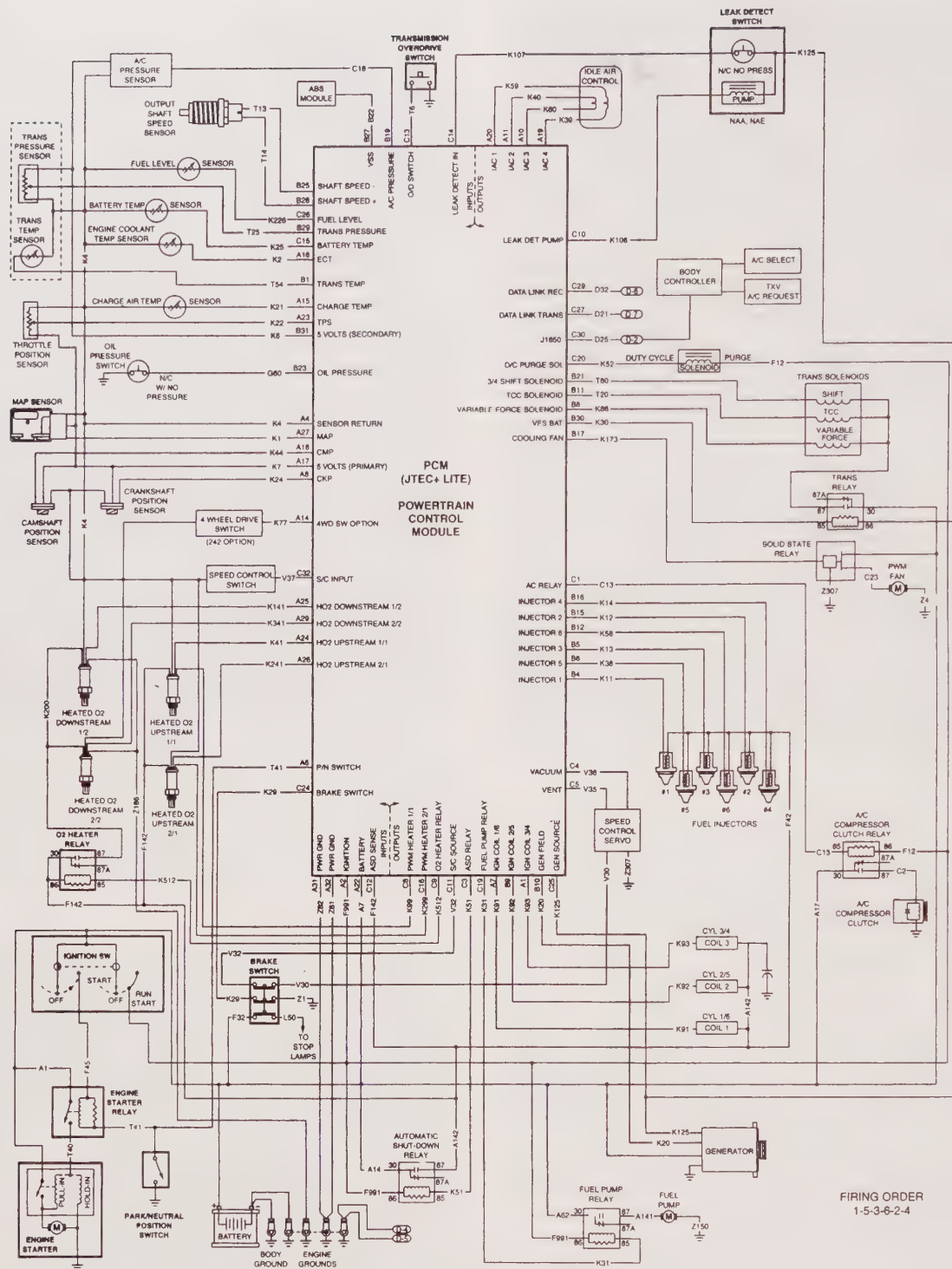


Figure 3-46. Schematics are like road maps of the electrical and vacuum systems. You will have a difficult time finding electrical problems without the proper schematic. (Chrysler)

technical hotline. Calling these hotlines will connect you with a technical support person. Hotline personnel often have information gathered from actual repairs and diagnosis situations. This is a way of obtaining real life information that would otherwise not be available. Manufacturer hotlines will also have access to the latest update information from the manufacturer's engineering departments.

Some vehicle manufacturer hotlines are available only to the technicians who work for that manufacturer's

dealerships. Other hotlines are available by subscription. These hotlines can be accessed after a yearly fee is paid. Some parts manufacturer hotlines are available to anyone. These are primarily intended for the technician who has questions about the manufacturer's parts.

Another use for technical hotlines is computer reprogramming. If the vehicle computer needs updated software, it can sometimes be obtained from the manufacturer over the phone line.

Manual Transmission Diagnosis		
Complaint	Cause	Correction
Lubricant leaks.	1. Excessive amount of lubricant in transmission. 2. Loose or broken clutch gear bearing retainer. 3. Clutch gear bearing retainer gasket damaged. 4. Shift cover loose or gasket damaged. 5. Shifter shaft seal leaks. 6. Countershaft loose in case. 7. Lack of sealant on bolts. 8. Worn extension oil seal.	1. Drain to correct level. 2. Tighten or replace retainer. 3. Replace gasket. 4. Tighten cover or replace gasket. 5. Replace shifter shift lip seal. 6. Replace case. 7. Coat bolts with sealant. 8. Replace seal.
Hard shifting.	1. Clutch not releasing or slow to release. 2. Shift linkage binding or selector not properly adjusted. 3. Downshifting at high speed.	1. Adjust or repair clutch. 2. Free up and adjust. 3. Instruct driver.
Falls out of gear.	1. Improperly adjusted linkage. 2. Transmission loose at clutch housing. 3. Debris between transmission case and clutch housing. 4. Clutch gear bearing retainer broken or loose. 5. Damaged mainshaft pilot bearing rollers. 6. Clutching teeth worn or defective and/or clutch hub spline worn. 7. Clutch housing misaligned with engine.	1. Adjust linkage. 2. Tighten mounting bolts. 3. Clean mating surfaces. 4. Tighten or replace clutch gear bearing retainer. 5. Replace pilot bearing rollers. 6. Replace gear, clutch sleeve, and clutch hub. 7. Shim transmission or replace clutch housing.
Noisy in all gears.	1. Insufficient lubricant. 2. Worn countergear bearings. 3. Worn or damaged clutch gear and countershaft drive gear. 4. Damaged clutch gear or mainshaft ball bearings. 5. Damaged speedometer gears.	1. Fill to filler plug opening. 2. Replace countergear bearings and shaft. 3. Replace worn or damaged gears. 4. Replace damaged bearings. 5. Replace speedometer gears.
Noisy in direct gear.	1. Damaged clutch gear bearing. 2. Damaged mainshaft bearing. 3. Damaged speedometer gears.	1. Replace damaged bearing. 2. Replace damaged bearing. 3. Replace speedometer gears.
Noisy in reduction or overdrive gears.	1. Insufficient lubricant. 2. Worn or damaged clutch gear or countergear. 3. Worn or damaged mainshaft constant-mesh gear. 4. Worn or damaged countergear teeth.	1. Fill to filler plug opening level. 2. Replace worn or damaged gears. 3. Replace worn or damaged gear. 4. Replace worn or damaged countergear.
Noisy in neutral with engine running.	1. Damaged clutch gear bearing. 2. Damaged mainshaft pilot bearing rollers.	1. Replace damaged bearing. 2. Replace bearing rollers.

Figure 3-47. Typical troubleshooting chart found in most service manuals.

Internet Resources

The Internet has become a valuable source of automotive repair information. Many manufacturers have Web sites (locations on the Internet) containing much technical information. Organizations such as The International Automotive Technicians Network (iATN) provide a way for technicians from around the world to help each other by way of email, **Figure 3-48**.

Work Orders

Work orders, or repair orders, are used to record shop activities regarding each vehicle brought to the shop. Modern work orders are often computer generated, although paper work orders are still in use. Always begin a work order by entering the date and filling out the customer information section with the customer's name, address, and contact phone numbers. List the vehicle information, such as the make, model, and vehicle identification number (VIN). Many computer programs save the data from previous visits, and this data can be called up and added to the current form. After all of the basic information has been entered, the next step is to record the vehicle concern that has brought the owner into the shop. Be sure to include a description of what the shop will do to address the concern.

After gathering all necessary information, ask the customer to sign the work order. A signed work order serves as a contract between the repair facility and the customer that describes the work to be done.

After the work is finished, write down all work performed and the time taken (labor time) to complete the repairs. In many cases, you will complete more than one repair job on a vehicle. Separate the labor for each repair job performed. Then, using the shop's labor rate, calculate

the labor cost for each job and write it on the work order. Total all labor costs at the bottom of the labor column.

List the parts needed to perform the work along with the price of each. Ordinarily, the shop will charge the list price, or retail price, for parts, not the price the shop paid. Total the part prices and enter this total in the proper space on the work order.

If any outside, or subcontracted, work was performed, add the total of this work to the work order. Examples of outside work include machine shop work, transmission/transaxle repair, upholstery repair, or other specialized labor.

Many shops make a charge for supplies, such as rags and cleaners. This may be a flat charge or a percentage of the total labor and parts costs. Add the supply charge to the total before calculating the sales tax. In many instances, there are required disposal fees for oil, antifreeze, tires, or other hazardous or problematic wastes. These fees must be added to the work order and, depending on the shop's location, may be subject to tax.

Total all costs for labor, parts, outside work, and fees on the work order. Add all applicable tax to the total. This completes the repair order.



Note: When filling out a work order, it is often helpful to think in terms of the three Cs of automotive repair—concern, cause, and correction. It is important that the customer's concern (reason the vehicle was brought in for service) be accurately recorded, the cause (problem causing the concern) be fully documented, and the correction (repair) be clearly stated on the work order. Following the three Cs model will help ensure that the customer's concern is addressed; that the appropriate diagnostic, service, and repair procedures are taken; and that the work performed on the vehicle is properly documented on the work order.

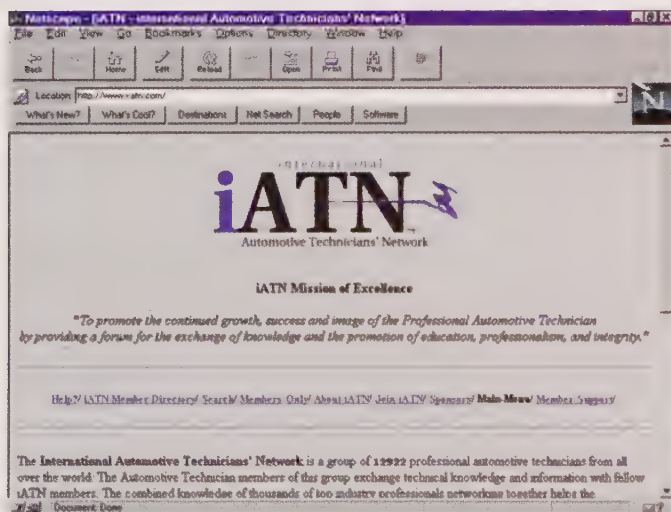


Figure 3-48. The Internet can be a good source of technical information. Some Internet sites allow technicians to ask questions and share information about difficult problems.

Summary

Special service tools are often needed to repair drive train parts. These tools are made specifically for troubleshooting or repairing a particular component or a group of similar components.

There are many special service tools, most of which can be purchased from independent parts suppliers. Other tools must be purchased from special tool manufacturers listed in vehicle service manuals.

Special wrenches are designed to turn fasteners that have odd head shapes or that are positioned so they cannot be reached with the more common hand wrenches.

Punches and drifts are special service tools for removing small pins or shafts. They are used with a hammer. Picks and snap ring pliers are designed to remove snap rings or other small parts.

Hydraulic presses are useful for removing or installing press-fit parts. Various adapters must be used during

disassembly and reassembly of bearings to securely hold them in place. Presses should always be used carefully.

Drivers are used to install bearings or seals in housings. They must be used carefully so that the part is installed correctly. Some drivers are used in combination with a hydraulic press, while others are struck with a hammer.

Pullers are used to remove press fit parts such as bushings, bearings, or seals. These pullers operate by applying pressure through screw threads or by the impact of a weight sliding on a shaft.

Alignment tools are used to keep drive train parts in alignment. An example is the clutch disc alignment tool. Flywheel locking and turning tools are used to turn the flywheel to gain access to fasteners or to lock the flywheel thoroughly.

Drain pans prevent a potentially dangerous mess by catching oil that would otherwise end up on the shop floor.

Screw extractors are used to remove broken fasteners from parts. Some extractors are designed to grip the fastener from the outside. Others are used internally by drilling a hole into the broken fastener.

Holding fixtures are useful for holding large, heavy components, such as transmissions and transaxles. Some holding fixtures can be used only on one kind of transmission, while others are designed to fit many types of transmissions and transaxles.

Transmission jacks make transmission removal and replacement much easier. Some jacks are used under the vehicle, while others are used when the vehicle is raised on a hoist. To prevent injury and accidents, transmission jacks should always be used if available.

Drive train components collect large amounts of dirt, sludge, and metal particles, and they must be carefully cleaned. Parts cleaners are necessary to thoroughly clean drive train parts. They should be used according to manufacturer directions.

There are many gauges available. Size gauges are used to measure a size or clearance. Angle gauges measure angles.

Micrometers can make very precise size measurements. To accurately use a micrometer, the micrometer must be carefully tightened on the part and then read. Micrometer reading varies for inch-based and metric-based micrometers.

Hole and telescoping gauges are used to make accurate measurements of inside diameters. A depth micrometer is used to measure the depth of openings in machined surfaces. Calipers have movable legs or jaws to gauge the size of openings.

Feeler gauges are made in different thicknesses. They are used to gauge openings or gaps. They come in flat and wire varieties. Straightedges are flat bars used to gauge the straightness of parts they are placed against. Straightedges are often used in combination with feeler gauges.

Dial indicators are used for moving drive train parts to measure small amounts of movement. They are easy to use but must be carefully installed, adjusted, and read.

The torque wrench is used to apply torque to a part and to measure this torque at the same time. Torque wrenches are usually used to tighten fasteners and are sometimes used to measure bearing preload. There are

many varieties of torque wrenches. Always consult factory tightening specifications before tightening a part.

Some electrical and electronic testers are needed to diagnose and service drive trains. These include test lights, multimeters, and scan tools. Service literature must also be used to obtain tightening values and sequences, repair procedures, and other specifications. In addition to the traditional service literature, CD-ROM discs, telephone hotlines, and the Internet are available. The appropriate service literature must be used to properly repair a drive train.

Review Questions—Chapter 3

Answer the following questions using the information provided in this chapter.

- _____ tools are exclusively designed to service a specific component or a specific class of components.
- _____ are special tools used to tighten large parts or to hold a part while another tool is used.
- _____ pliers have special jaws that fit and grasp the snap ring.
- A press fit is an example of a(n) _____ fit.
(A) clearance
(B) shrink
(C) interference
(D) running
- List three safety rules to follow when using pullers.
- Seal protectors are used to keep a seal from being damaged by sharp edges on _____.
- Why might you use a flywheel turning tool?
- When removing and installing transmissions, _____ should be used.
- A _____ may be used to determine whether current is flowing through a switch, relay, solenoid, electrical connection, wire, or other electrical component.
- _____ are combination meters capable of measuring ohms, volts, and amps.
- Overhaul manuals contain comprehensive information needed to _____, _____, and _____ vehicle components.
- Many vehicle manufacturers have _____ on the Internet.

ASE-Type Questions—Chapter 3

- Each of the following statements about spanner wrenches is true *except*:
(A) they are sometimes used to tighten large parts.
(B) they are sometimes used to hold parts while other tools are being used.
(C) they are designed to fit standard 3/8" or 1/2" ratchets.
(D) some are bolted to the part they hold.

2. Technician A says that a punch should be placed against the part to be removed before striking the punch with a hammer. Technician B says that both punches and chisels can be struck with a hammer. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
3. Technician A says that snap ring pliers can be used for both removing and installing snap rings. Technician B says that picks should *never* be used to remove snap rings or retainers. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
4. Each of the following can be installed by the use of drivers *except*:
(A) seals.
(B) O-rings.
(C) bearings.
(D) bushings.
5. Technician A says that some pullers remove parts by the use of screw force or impact. Technician B says that some pullers remove parts by the use of hydraulic pressure. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
6. Multimeters can be used to measure each of the following *except*:
(A) amperage.
(B) pressure.
(C) voltage.
(D) resistance.
7. Technician A says that telephone hotlines are maintained by vehicle manufacturers. Technician B says that telephone hotlines are maintained by some parts manufacturers. Who is right?
A. A only.
B. B only.
C. Both A and B.
D. Neither A nor B.
8. Technician A says that flywheel turners are bolted to the engine or another stationary part of the drive train. Technician B says that flywheel turners engage the teeth on the flywheel ring gear. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
9. Cold-soak tanks and hot tanks are types of _____.
(A) parts washers
(B) steam cleaners
(C) flushers
(D) drain pans
10. A scan tool is used to perform which of the following tasks?
(A) Check transmission pressures.
(B) Measure intake manifold vacuum.
(C) Measure bolt torque.
(D) Retrieve trouble codes.
11. Each of the following is a type of size gauge, *except*:
(A) micrometers.
(B) calipers.
(C) torque wrenches.
(D) dial indicators.
12. A flywheel is being checked for excessive warping. Technician A says that a feeler gauge and straightedge can be used to make this check. Technician B says that a dial indicator can be used to make this check. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
13. Technician A says that some threaded fasteners do *not* have torque values. Technician B says that an experienced technician does *not* need to use a torque wrench. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
14. Each of the following requires a telephone or other electronic connection to a remote location *except*:
(A) CD-ROMs.
(B) email.
(C) websites.
(D) hotlines.
15. Technician A says that schematics contain steps needed to logically diagnose a problem. Technician B says that schematics are used to trace electrical circuits. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.



Chapter 4

Gears, Chains, and Bearings

After studying this chapter, you will be able to:

- ☐ Identify certain basic parts of a gear.
- ☐ Discuss gear reduction and overdrive.
- ☐ Name and describe types of gears found on drive trains.
- ☐ Calculate gear ratio.
- ☐ Describe the construction and explain the operation of a planetary gearset.
- ☐ Summarize basic methods of gear removal and inspection.
- ☐ Discuss common gear problems.
- ☐ Describe the construction and explain the operation of a chain drive.
- ☐ Summarize general methods of chain drive lubrication and inspection.
- ☐ Discuss aspects of the different types of bearings.
- ☐ Summarize fundamental methods for servicing bearings.

Technical Terms

Gear	Face	Damage	Running fit
Gear drive	Face width	Pitting	Race
Spur gear	Root	Spalling	Ball bearing
Helical gear	Whole depth	Peening	Roller bearing
End thrust	Pitch circle	Scoring	Straight roller bearing
Herringbone gear	Circular thickness	Welding	Tapered roller bearing
Double-helical gear	Working depth	Chain drive	Needle bearing
Bevel gear	Clearance	Sprocket	Thrust bearing
Spiral bevel gear	Gear backlash	Roller chain	Thrust washer
Hypoid gear	Gear ratio	Silent chain	End clearance
Worm gear	Gear reduction	Chain tensioner	Retainer plate
Rack-and-pinion gear	Direct drive	Bearing	Collar
Planetary gearset	Overdrive	Friction bearing	Spline
Sun gear	Countershaft gear assembly	Antifriction bearing	Splined shaft
Planet gear	Reverse idler gear	Radial load	Key
Ring gear	Wear	Axial load	Keyway
Planet carrier	Failure	Oil clearance	

Introduction

All vehicle drive trains, no matter how complex, are made up of simple parts. Parts such as gears, chains, and bearings are the building blocks of the drive train. These parts can be arranged in many ways to create durable and efficient devices that can transmit and modify engine power as needed.

Engine power is transmitted by the action of gears—engine torque is multiplied, rpm is reduced, and vehicle direction is reversed. Chains and sprockets also accomplish these actions. Although simple gears and chains are arranged into complex drive train mechanisms, their basic design does not vary.

All shafts and other rotating parts of the drive train revolve around bearings. Without bearings, the moving parts of the drive train would encounter too much friction, resulting in wasted engine power and premature part wear. Drive trains use many kinds of bearings, but they all serve the same purpose: to reduce friction and improve efficiency.

In this chapter, you will learn how gears, chains, and bearings function. You must understand how these operate before you begin to study more complex drive train parts. In later chapters, you will see how these simple parts are combined in transmissions, transaxles, and rear axle assemblies.

Remember, the inspection and service procedures covered in this chapter should always be performed when drive train components, such as transmissions or differentials, are overhauled. Learning to perform these tasks now will allow you to concentrate on overall service procedures as they are presented in later chapters.

Gear Drives

A simple **gear** is a toothed wheel. In operation, gears engage other gears or mechanical parts for the purpose of transmitting power. Such a system is referred to as a **gear drive**. The gear that transmits the power is called the drive gear; the one that receives the power is called the driven gear. Gears provide positive (non-slipping) power transmission. Gears that are engaged are said to be in mesh. Gears can be used to increase or decrease turning speeds. They are often used to increase torque. Another use is maintaining proper timing between two rotating parts, such as an engine crankshaft and camshaft.

A gear that is used in a drive train is usually made of high-strength steel. In its manufacture, a gear blank—a steel disk without any features—is produced from relatively soft steel. The gear teeth are cut on a special machine. The most common type of gear-making machine is a gear shaper. Once the teeth are cut, the parts of the gear that will contact other moving parts are ground and polished to a smooth finish. The finished gear is hardened by a heat-treating process. The process makes a durable gear and allows for a precision fit.

Gears that are used in light service are often made of brass, aluminum, fiber material, or plastic. These materials are cheaper, and they permit quieter operation. Some examples are speedometer drive gears, engine distributor gears, and the internal gears found in many electric motors.

Types of Gears

There are a number of different types of gears available. Many of these are commonly used on automotive drive trains. Types of gears include spur gears, helical gears, herringbone gears, bevel gears, hypoid gears, worm gears, rack-and-pinion gears, and planetary gears.

Spur gears

Spur gears are used to connect parallel shafts. The teeth on spur gears are always cut straight across, or axially. In other words, they run parallel to the axis of rotation. Spur gears are found most often in manual transmissions, where gears must be manually moved in and out of engagement. The straight cut of the teeth allows a smooth engagement and disengagement. Spur gears are inexpensive to manufacture. A disadvantage to these gears is that they become noisy if the clearance between mating gears becomes too large. Typical spur gears are shown in **Figure 4-1**.

Helical gears

Helical gears are similar to spur gears. They, too, are used to connect parallel shafts. However, the teeth of helical gears are cut at an angle, called a helix angle, across the gear surface. A helical gear is shown in **Figure 4-2**. Helical gears operate more smoothly and quietly than spur gears. The engagement of individual teeth is a gradual sliding motion, and several teeth are engaged at once. Helical gears are often used for the forward gears of manual transmissions where high gear speeds make smooth, quiet operation all the more important. The sliding action of the teeth causes more friction than encountered by spur gear teeth. As a result, helical gears must be kept well lubricated.

A thrusting action occurs along the shaft whenever power is transmitted through a helical gear. This is due to

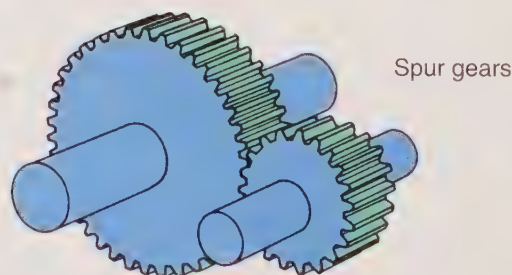


Figure 4-1. The simplest gear found in automotive drive trains is the spur gear. Spur gear teeth are cut axially, or parallel to the gear axis of rotation. These gears are strong, but they may become noisy if the clearance between the teeth of the mating gears becomes too great. (Deere & Co.)

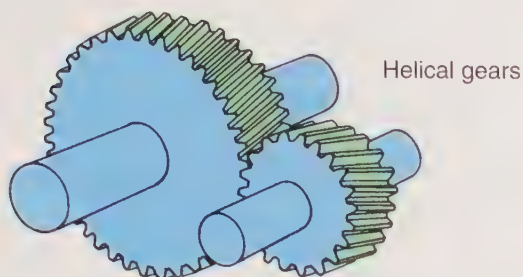


Figure 4-2. Helical gear teeth are cut at an angle. Helical gears are used in many places, including transmissions and final drives. Helical gears provide smoother and quieter power transmission than do spur gears because the meshing of teeth is more gradual. (Deere & Co.)

the helix angle. See **Figure 4-3**. This action is called **end thrust**. Two meshing helical gears will try to push each other in opposite directions. If end thrust is too large, the gears will disengage. Thrust washers or thrust bearings are often used to control end thrust.

Herringbone and double-helical gears

The **herringbone gear** is a variation of a helical gear. It is sometimes used to overcome the end thrust problems of helical gears. A typical herringbone gear is shown in **Figure 4-4**. The thrust forces of the two sides of the herringbone gear cancel each other. The herringbone gear operates more like a spur gear.

A variation of the herringbone gear is called a **double-helical gear**. This gear differs in that the opposing teeth have a space between them. Herringbone gears and double-helical gears are expensive to machine, and they

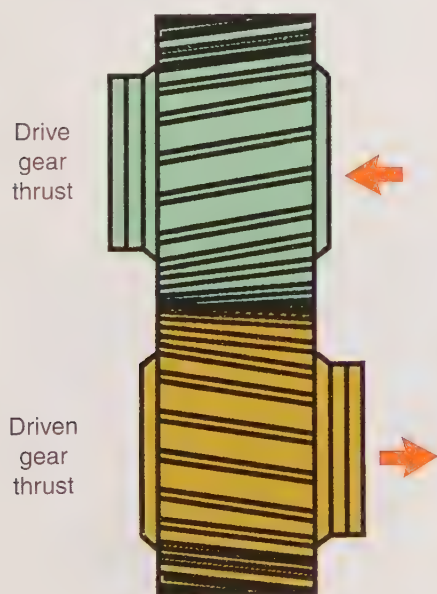


Figure 4-3. The action of helical gears tends to push the gears away from each other. This puts pressure on the gears and on the shaft on which they ride. The pressure must be controlled by other parts in the drive train, or gear movement will be excessive.

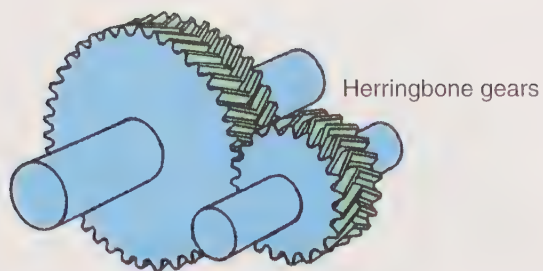


Figure 4-4. Herringbone gears consist of two mating helical gears, each angled in opposite directions. The design of this gear eliminates some of the problems experienced by other gears such as end thrust in helical gears. These gears are expensive, and they do not work well at high speeds. They are seldom used on vehicle drive trains. (Deere & Co.)

do not work well at high speeds. For these reasons, they are rare in automotive drive trains.

Bevel gears

When axes of rotation are not parallel, **bevel gears** are used, **Figure 4-5**. Bevel gears connect shafts that run at angles. In vehicle drive trains, the angle is usually 90° , but bevel gears can be used to achieve any angle. The bevel gear resembles a truncated cone, a cone with the top cut off. Bevel gears are used, for example, in the differential assembly.

Spiral bevel gears

A variation of the bevel gear is the **spiral bevel gear**, shown in **Figure 4-6**. Whereas bevel gear teeth are straight, spiral bevel gear teeth are curved. Since the teeth gradually engage and the parts of more than one tooth are always engaged, the spiral bevel design results in smoother power transfer. However, the sliding action of spiral bevel teeth means that lubrication is even more critical than for straight bevel teeth.

Hypoid gears

Hypoid gears, **Figure 4-7**, like bevel gears, are used in applications where power flow must be diverted by some angle. Hypoid gears are similar to spiral bevel gears except

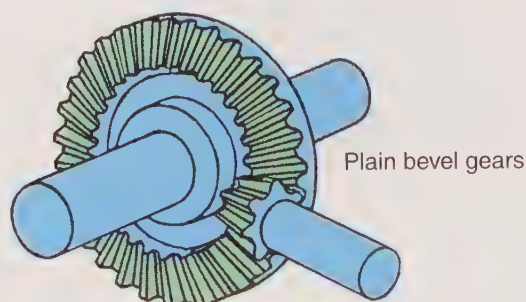


Figure 4-5. Bevel gears can be used to change the course of power flow by some angle. The angle is usually 90° in vehicle drive trains. (Deere & Co.)

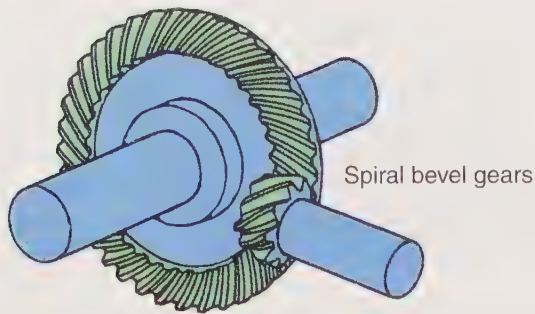


Figure 4-6. A spiral bevel gear has curved, in addition to beveled, gear teeth to allow a gradual meshing of teeth. This gear combines the angle change feature of the bevel gear with the smooth operation feature of the helical gear. (Deere & Co.)

that the shaft axial centerlines (rotational axes) do not intersect. One gear is set at a lower or higher point in relation to the other, and the centerlines of the two do not meet. The most common use of hypoid gears is in the rear axle assembly: the ring and pinion of the differential assembly are hypoid gears.

Worm gears

Worm gears, Figure 4-8, also connect shafts that run at an angle. When worm gears are used, the angle is always 90°. A worm gearset has two major components—the worm and the worm wheel. Worm gears are often used when a large speed reduction is needed. Except for the speedometer drive, they are seldom used on drive trains. Outside of the drive train, they may be found on power takeoffs used to operate vehicle-mounted winches and other equipment.

Rack-and-pinion gears

Rack-and-pinion gears, Figure 4-9, are usually associated with the vehicle steering system. The rack is a flat bar with teeth cut into it. The pinion is a small gear. The rack-and-pinion converts rotary motion into linear (straight line)

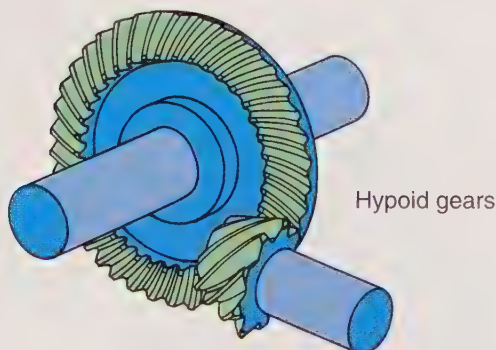


Figure 4-7. The hypoid gear is a variation of the bevel gear. The hypoid system is used when the gear shaft axes are at different levels. Hypoid gears are used extensively in rear-wheel drive vehicles. The drive gear can be placed lower in the rear axle housing to allow the drive shaft hump to be smaller. (Deere & Co.)

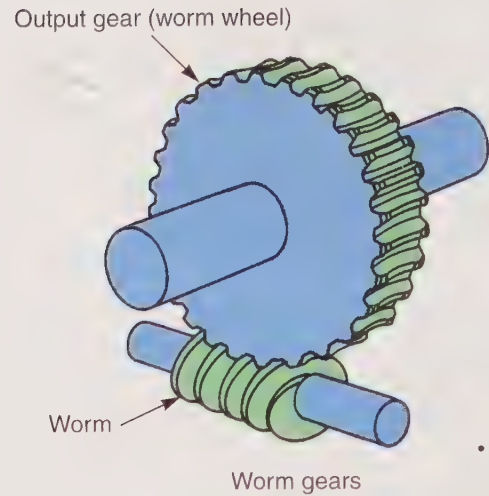


Figure 4-8. The worm gear is used when a large speed reduction is needed and the gear shafts do not have to be on the same plane. These gears are seldom used on most drive trains, except for the speedometer drive. (Deere & Co.)

motion when the pinion drives the rack. If the rack drives the pinion, linear motion is converted into rotary motion.

Planetary gearsets

Planetary gearsets are gear assemblies used in transfer cases and in manual transmissions with overdrive units. They are also used in automatic transmissions. Planetary gearsets provide gear reduction and direct drive. They also provide overdrive.

A planetary gearset, as shown in Figure 4-10, consists of three types of gears: a **sun gear** in the center; **planet gears**, or **planet pinions**, surrounding and meshed with the sun gear; and a **ring**, or **annulus**, gear meshed with the planet gears. The planet gears are attached to a **planet**, or **planet-pinion**, **carrier**, yet they are free to rotate.

The unique feature of a planetary gearset is that all gears are in constant mesh. In driving power through the

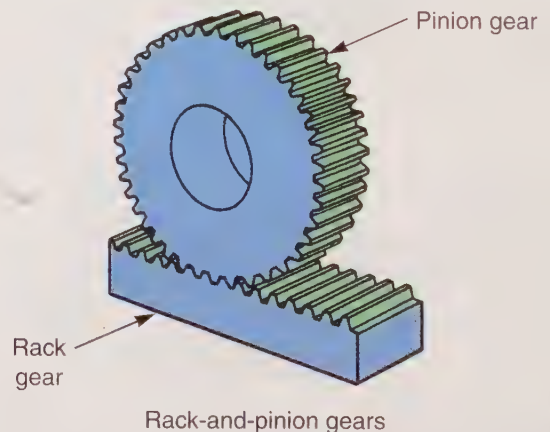


Figure 4-9. Rack-and-pinion gears are used in steering systems. The pinion gear is actually a spur gear. The spur gear teeth mate with matching teeth on the rack. (Deere & Co.)

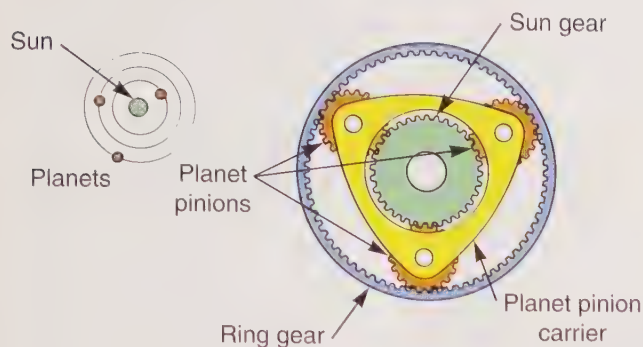


Figure 4-10. A planetary gearset somewhat resembles our solar system. Planetary gears are in constant mesh. Gears rotate or are held stationary in different combinations to achieve different gear ratios. A single gearset can be used to provide reduction, direct drive, overdrive, and reverse. (Deere & Co.)

gearset, one of the three gear types—sun, ring, or planet—will be held stationary; the other two will rotate, serving as input and output. Different combinations of input, output, and stationary gears are used to achieve different effects—for example, an increase or decrease of speed. A system will be in Neutral when all three gears are free.

Gear Nomenclature

There are terms to describe almost every possible dimension of a gear. Design drafters and machinists involved in gear manufacturing are very familiar with these terms. Automotive technicians do not need to know every term. This is because servicing drive train gears usually means replacing the damaged gear with an exact duplicate of the original. However, to aid in obtaining the proper replacement gear, the technician should know a few common gear terms. Some of these are given in **Figure 4-11**.

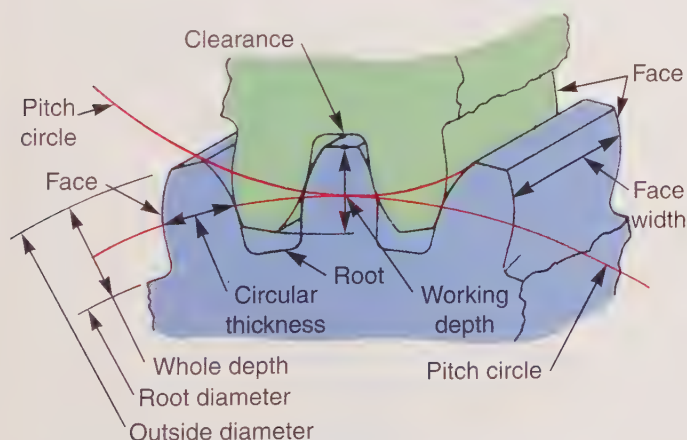


Figure 4-11. Basic gear terms should be learned to help understand gear operation. Gear faces are the contact surfaces of gear teeth. The faces carry the load of the gears. Depth and width of the teeth are critical for proper gear operation. Backlash is the clearance at the pitch circle between faces of two mating

The contact surfaces of gear teeth are called **faces**. The width of the tooth measured parallel to the gear axis is the **face width**. The base of the gear tooth is called the **root**. The distance from the outside diameter of the gear to the root diameter is the **whole depth**. Stated another way, the whole depth is the distance from the top of the tooth to the root. The face width and whole depth should be measured, and the number of teeth should be counted when obtaining replacement gears.

An imaginary circle around the gear located at about midway between the outside diameter and the root diameter is the **pitch circle**. Pitch circles of two mating gears are tangent to one another. **Circular thickness** is the thickness of a tooth measured between its faces and along the pitch circle. The **working depth** is the overlap measured between outside diameters of the two gears. The space between the root of one tooth and the top of the mating tooth is referred to as **clearance**.

Gear backlash is a term the technician will commonly use. Backlash is the amount by which the space between neighboring gear teeth exceeds circular thickness of a mating gear tooth. The difference is figured at the pitch circles. In general, the greater the amount, the more play there will be between two meshing gears. The degree of backlash must be correct for quiet gear operation and long gear life. On some gear trains, the backlash can be corrected by adjusting the positions of the gears. On others, the gears must be replaced to obtain the proper backlash. Some gears, by design, have less backlash problems than others. Herringbone gears, for example, are better in this respect than spur gears.

Gear Ratio

You are probably familiar with the term **gear ratio**. It is the speed relationship between two gears. The gear ratio is determined by the difference in the number of teeth between two gears. Mathematically, it is the ratio of the number of teeth on the driven gear to the number of teeth on the drive gear. This is the same as saying it is the number of teeth on the driven gear divided by the number of teeth on the drive gear.

Figure 4-12 is an example of gear ratio. In the illustration, the driven gear has 90 teeth. The gear that drives it, or the drive gear, has 30 teeth. The ratio between the two gears is found to be: 90/30 (90 divided by 30), which equals 3/1 and is expressed as 3:1 (read as “3 to 1”).

The gear ratio relates the speed of the drive gear to the speed of the driven gear. A 3:1 gear ratio is an example of what is called **gear reduction**. A 3:1 gear reduction means that it takes three revolutions of a drive gear to turn the driven gear one whole revolution. Refer to **Figure 4-12A**. A set of gears with a ratio of 3:1 is considered a reduction gearset. This is because the speed at the output shaft will be less than the speed of the input.

While a reduction gearset reduces speed, it has the opposite effect on torque; the reduction gearset multiplies torque. For example, with a 3:1 reduction gearset, 1 ft lb

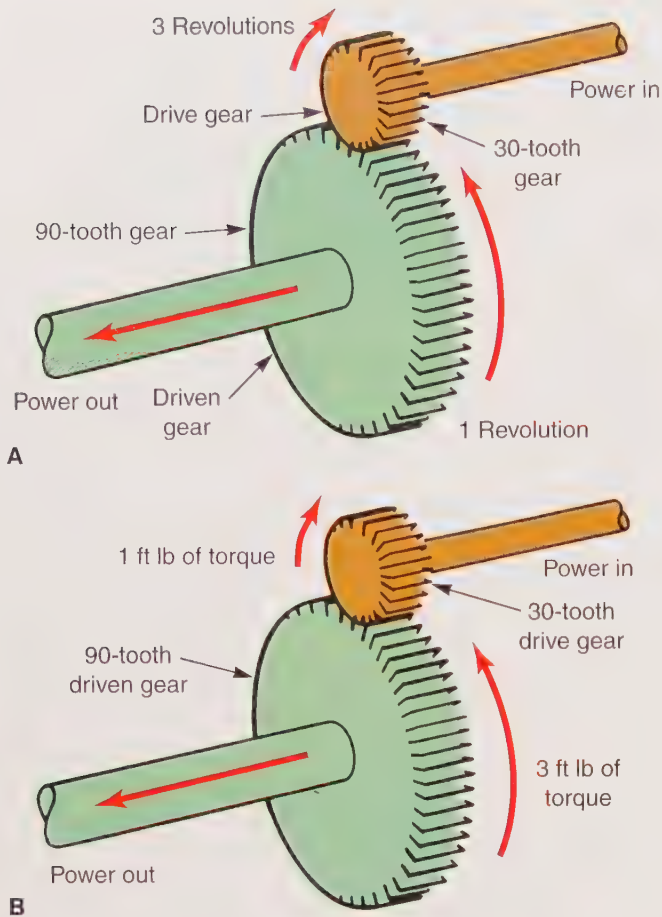


Figure 4-12. A reduction gearset arrangement, which reduces speed while increasing torque, is shown. A—The output shaft completes one revolution for every three of the input shaft. B—A torque of 1 ft lb (1.35 N•m) on the input shaft translates to 3 ft lb (4.05 N•m) on the output shaft.

(1.35 N•m) of torque on the drive gear generates 3 ft lb (4.05 N•m) on the driven gear. Refer to **Figure 4-12B**.

To sum up these mathematical relationships:

$$\begin{aligned} \text{gear ratio} &= \frac{\text{number of teeth on driven gear}}{\text{number of teeth on drive gear}} \\ &= \frac{\text{rpm of drive gear}}{\text{rpm of driven gear}} \\ &= \frac{\text{ft lb on driven gear}}{\text{ft lb on drive gear}} \end{aligned}$$

A vehicle requires different gear ratios for different operating conditions. For instance, internal combustion engines develop only minimal torque when engine speed is low. To overcome this problem, reduction gearsets are used in the transmission. A typical reduction in low gear is about 3:1. For example, a 900-rpm engine speed would be reduced to 300 rpm at the transmission output. At the same time speed is reduced, torque is multiplied. So, if 50 ft lb (67.5 N•m) of torque enters the gears, 150 ft lb (202.5 N•m) of torque leaves. The reduction gearset serves as a torque-multiplying device to get the vehicle moving at low speeds.

As vehicle speed increases, less torque is needed to keep the vehicle moving due to its inertia (resistance to change in state of motion). Also, the engine is turning faster and is producing more power. The vehicle can then

be shifted into a gear with less reduction, such as 2:1. As an example, an engine speed of 1500 rpm will be reduced to 750 rpm at the transmission output, and an engine output of 75 ft lb (101.25 N•m) will be increased to 150 ft lb (202.5 N•m).

When the vehicle is moving at highway speeds, gear reduction is no longer needed or desired. The vehicle is shifted into high gear, which is direct drive. **Direct drive**, in which gears are not actually used to multiply power, has a gear ratio of 1:1. It allows the engine to run at reduced speed while maintaining vehicle speed. With this gear ratio, there is no change in either speed or torque between engine output and transmission output.

For greater fuel economy at higher speeds, **overdrive** is often employed. Most overdrive gearsets have a ratio of around 1:1.5 (sometimes written as 0.66:1). This means that an engine speed of 1000 rpm will exit the transmission at 1500 rpm. With this type of ratio, there is a speed increase through the gearset. This allows the engine to run more slowly than a higher gear ratio would permit at the same speed of travel. Since the engine is running more slowly, it will use less fuel and last longer.

Reverse Gear

Simple gears can be arranged to reverse direction. In the normal action of two mating gears, the drive gear and driven gear rotate in opposite directions. A third gear will restore the original direction of rotation, which has been reversed by the second gear. A manual transmission, for instance, employs a **countershaft gear assembly** between input and output shafts. The assembly consists of a shaft and several gears, which rotate as a unit. See **Figure 4-13**.

To change directions, a vehicle has a **reverse gear**, which is part of the transmission. **Figure 4-13** shows reverse gear engaged. Note the use of the **reverse idler gear**, or simply, the **idler gear**, turning the output shaft in the same direction as the countershaft gear assembly, which is opposite to the direction of the input shaft. The reverse idler gear does not change the gear ratio.

Gear Removal

It helps to know a little bit about the ways gears are installed before discussing how to remove them. Gears are joined or fit onto their shafts in several different ways. Commonly, gears are press fit on the shaft. In contrast, many gears slip over the shafts on which they ride. Such gears are held in position by other parts of the drive train or by snap rings. If the gear must turn with its shaft, it is held by a key that fits into matching slots in the gear and shaft. These slots are called keyways. (Keys and keyways are covered later in this chapter.) In many cases, a gear and shaft is a solid unit machined from a single casting. If the gear teeth are damaged, the entire part must be replaced.

There are a couple of ways to go about removing gears from their shafts. The method depends on the way the gear is held onto its shaft. Gears that are held in place

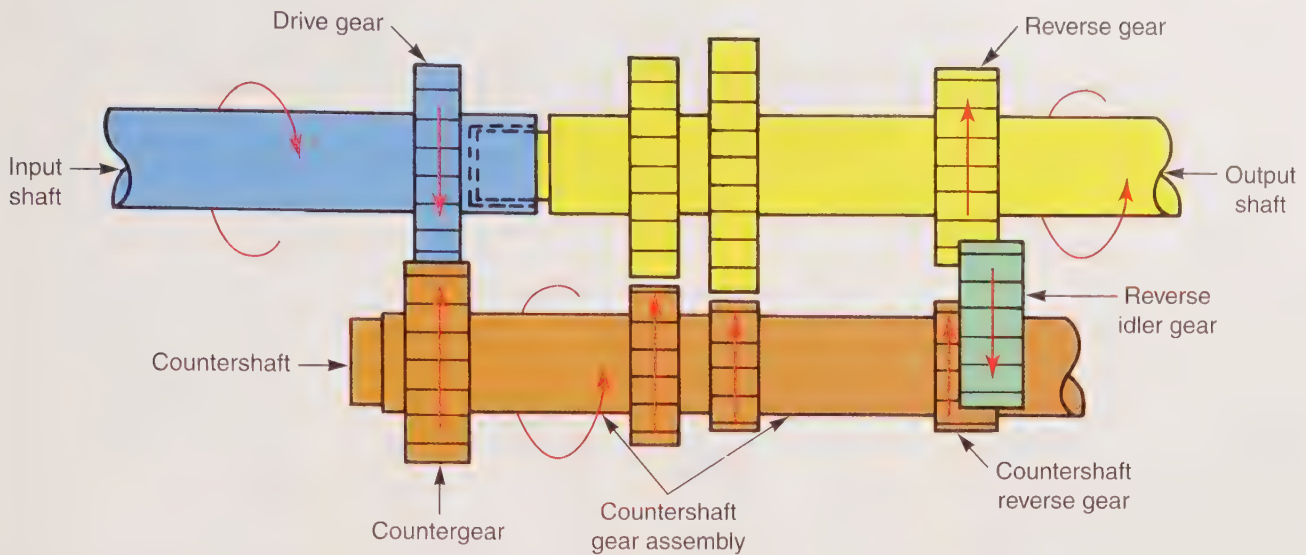


Figure 4-13. Simplified drawing of a transmission with reverse gears engaged. The countergear causes the countershaft gear assembly to rotate opposite to the direction of the input shaft. The countershaft reverse gear meshes with the reverse idler gear, which meshes with the reverse gear of the output shaft. The reverse gears rotate in the same direction because of the reverse idler gear. Output shaft rotation is opposite of the input shaft.

by any kind of retainer will usually slide off the shaft once the retainer is removed. Removing press-fit gears requires the use of a gear puller or a press—either mechanical or hydraulic. The gear is pulled or pressed off. In some cases, the gear can be driven off, but this must be carefully done to prevent damage or injury. A typical gear removal operation using a press and an adapter is shown in **Figure 4-14**.

Gear Inspection

Gears should be inspected whenever there is evidence of gear problems or when they are removed from the vehicle

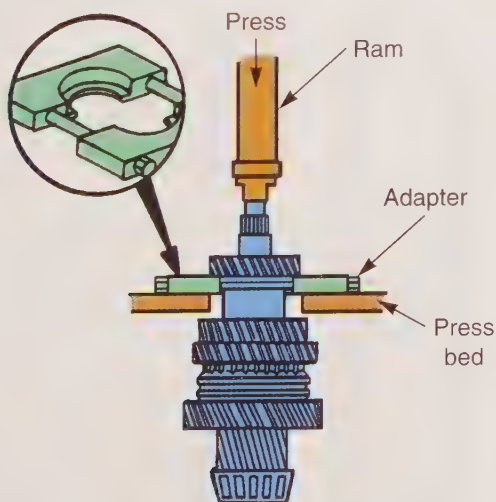


Figure 4-14. A press is shown in the process of removing a gear from a manual transaxle output shaft. The press pushes down on the shaft. The gear is restrained by the adapter plate, and, as a result, it comes off of the shaft. Other gears remain in place. (General Motors)

for any reason. Some of the problems to look for are wear, pitting, spalling, peening, scoring, and welding.

Wear is erosion of a surface caused by relative motion between two parts. Gears are subject to wear, and, given time, will wear out from use. In most automotive drive trains, the various gears are made to be durable. These gears will operate satisfactorily for many miles. Some gears, such as those of the rear axle assembly, will typically last for the life of the vehicle.

Gear wear can be responsible for gear **failure**—the total breakdown in structure so that it can no longer fulfill its purpose. A gear with normal wear from high mileage will appear worn but in good condition. A gear removed from a well-maintained vehicle with very high mileage may show considerable wear. In either case, the faces will show an even wear pattern and will appear smooth and shiny. They should be light gray in color.

At some point, gear wear may become so extreme that the teeth are too thin to support the loads that are placed on them. Such gears usually develop excessive backlash, which increases the shock loads on the teeth when they are first engaged. When this happens, a gear tooth may develop a crack and break. The broken tooth falls to the bottom of the gear housing; however, the gear may operate for a while longer. This increases the shock loads on the remaining teeth, causing other teeth to break. Sooner or later, the gear will fail completely.

Early gear failure is usually caused by a drive train defect, lack of lubrication, or abuse. The most common cause of gear tooth failure on a low mileage vehicle is abuse of the drive train. Placing heavy loads on a vehicle not designed to carry them can overstress the teeth and cause gear failure. Loading the gears too rapidly will cause shock loads, which can overload the teeth and break the gear. On a manual transmission vehicle, this may happen

when the clutch is engaged abruptly with the engine running at high speed.

Figure 4-15 shows some common types of gear **damage**. These are conditions short of failure. Left uncorrected, these problems of gear damage will lead to gear failure. A common gear problem is **pitting**. Pitting is evidenced by small holes, or pits, in the gear teeth. The pits reduce the gear contact area. If the cause of the problem is not corrected, the pits can become larger and more plentiful. Pitting is usually caused by abrasive particles or corrosion. These can be attributed to dirt, metal debris, or water in the lubricant.

Severe pitting can lead to **spalling**, a condition in which sections of the gear teeth flake or chip off. Spalling, like pitting, can also be caused by lack of lubricant or severe gear loads.

Another cause of gear failure is **peening**, which appears as indentations in the gear faces. Peening is usually caused by severe loads on the gear teeth or by large particles of foreign matter in the lubricant.

Scoring is another cause of gear failure. It appears as scratches on gear teeth faces caused by improper machining or lack of lubrication. If the scoring is not corrected, it will lead to spalling or a condition called **welding**. Welding occurs when mating gear teeth overheat, melt together, and then pull apart as the gear turns. This will quickly destroy the gear.

Sometimes lack of lubrication will cause the gears to overheat. Overheating will undo the heat treating applied in manufacturing to harden the gears. The gears become relatively soft, and they soon wear out. Overheated gear teeth usually turn a different color from the undamaged part of the gear. This color can vary anywhere from yellow to deep blue.

Chain Drives

A **chain drive** consists of a series of links, or a **chain**, and two or more gears called **sprockets**. The chain transmits

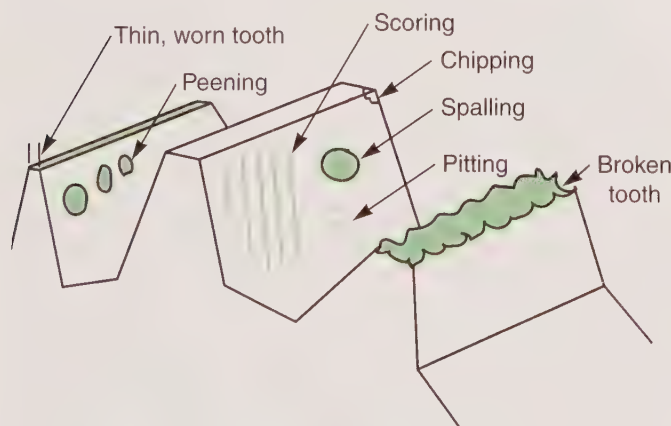


Figure 4-15. Excessive gear wear and some other problems leading to complete gear failure. Note that, in reality, gear teeth are likely to show just one kind of damage.

motion between the two sprockets. Chain drives have a positive driving action similar to that of two meshing gears. The sprocket teeth match the openings in the chain links and mesh with them to transmit power. One sprocket transmits power. It is called the drive sprocket. The other one receives the power and is called the driven sprocket.

Chain drives transmit power in a straight line between the two sprockets. This means of power transmission is compact. For this reason, chain drives are often used to connect torque converters to the transmission mechanical system in front-wheel drive vehicles where space is limited. Chain drives are found not only in transaxles, but in four-wheel drive transfer cases. These will be explained in later chapters. **Figure 4-16** is an example of a chain drive assembly.

Types of Chains

There are two types of chains used on modern vehicles. The more common is the **roller chain**, **Figure 4-17**. Roller chain is so called because it employs rollers that rotate on drive pins. The rollers contact the sprocket teeth. The spaces between the rollers match the size of the teeth. The rollers provide a rolling contact, which reduces friction between the chain and sprocket.

Roller chains can be thought of as alternating pin links and roller links. (Refer to **Figure 4-17**.) Roller links are coupled together with pin links. An enlarged view of a pin link is shown in **Figure 4-18**. Many chains have a master pin link, which is held together with a clip. The clip can be removed to separate the chain for easy replacement. Chain links vary in design, but all serve the same function.

The **silent chain**, **Figure 4-19**, is made up of a series of flat metal links, which provide quiet operation. These links have teeth that engage matching teeth in the sprockets. The

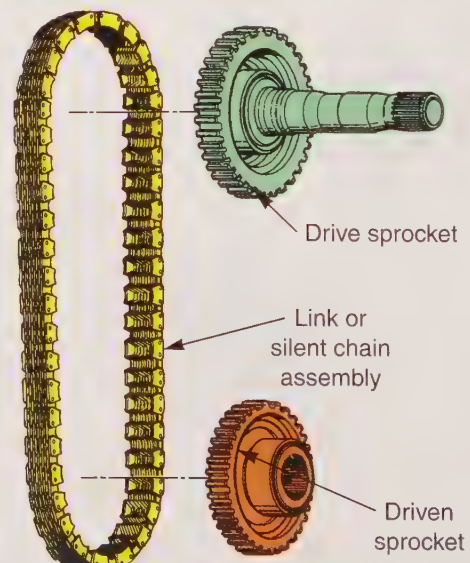


Figure 4-16. This is a typical chain drive assembly. The major parts of the chain drive are the chain and drive sprockets. Every system has at least two sprockets. (Ford)

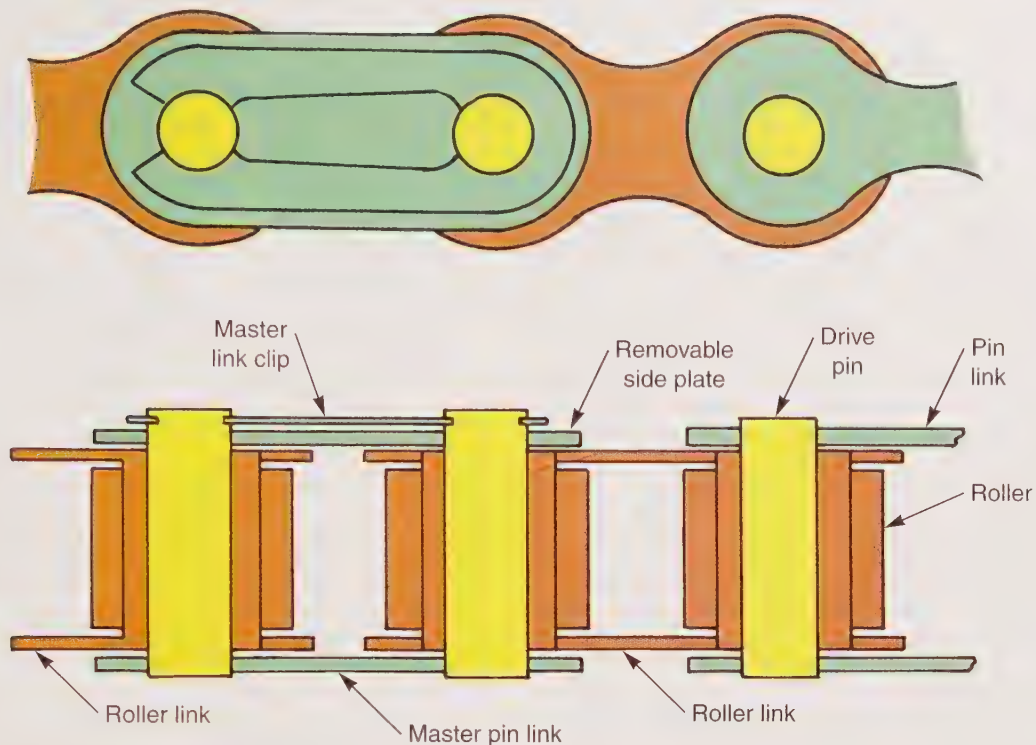


Figure 4-17. Roller chains are made up of pin links and roller links. The rollers mesh with the sprocket teeth, providing positive drive.

links are placed side by side. This creates a solid contact for engaging the sprocket. The links are held in alignment by pins that pass completely through the chain. This is opposite from the roller chain, wherein the pins (or rollers) engage the sprockets, and the links perform the task of alignment. The construction of the silent chain allows some internal movement of the chain parts. This reduces vibration and noise and partially compensates for wear and sprocket misalignment.

Chain Tensioners

Chains eventually wear. This can cause the chain to lose its tension. To prevent this, many chain drives have a

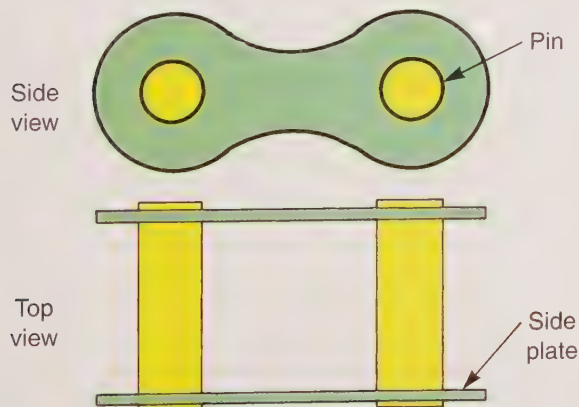


Figure 4-18. A pin link consists of two side plates riveted to two pins.

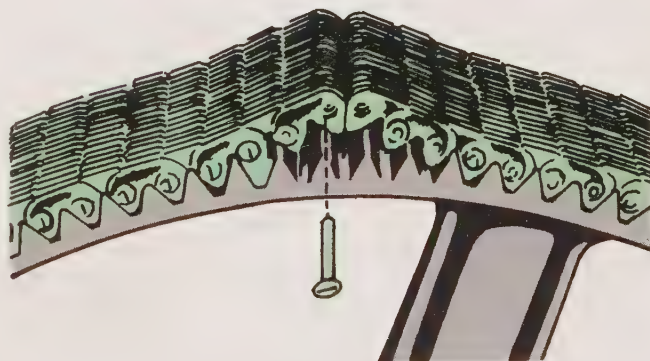
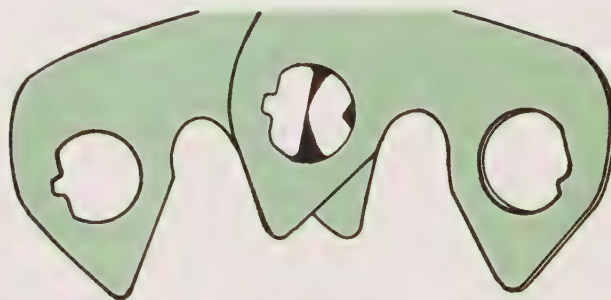


Figure 4-19. Silent chain construction differs from that of other chains. On a silent chain, the links are a series of toothed leaves that extend the entire width of the chain. The links engage the sprocket and are held in place by pins. The pins keep the links in alignment. This is just the opposite of the roller chain.

chain tensioner to take up the slack. Most chain tensioners are spring-loaded devices similar to that shown in **Figure 4-20**. They maintain constant pressure on the return, or nondrive, side of the chain.

One drawback of a spring-loaded chain tensioner is that as the chain wears, the tensioner exerts less tension on it. The spring extends further to take up the slack, and, eventually, the chain is too worn for the tensioner to have any effect. In most cases, the chain will become noisy before it fails completely.

Another type of tensioner is the hydraulic chain tensioner. This type uses system oil pressure to keep constant tension on the chain, even as parts wear. It is not as common as the spring-loaded tensioner.

Chain Drive Ratio

To find chain drive ratio, divide the number of teeth on the driven sprocket by the number of teeth on the drive sprocket. **Figure 4-21** shows how to find the ratio for a final drive that employs a chain drive.

As another example, assume that a driven sprocket has 30 teeth and the drive sprocket has 10 teeth. Dividing 30 by 10 gives 3. The gear ratio in this example is 3:1. This is a reduction ratio because for every 3 revolutions of the input, the output completes only 1 revolution. In other words, the speed of the output is less than the speed of the input.

If the driven sprocket had 10 teeth, and the drive sprocket had 30 teeth, the gear ratio would be 1:3. This would be an overdrive ratio because the speed of the output would be greater than the speed of the input.

If the drive and driven sprockets have an equal number of teeth, the ratio is 1:1. The input and output turn together. There is no multiplication of torque or increase of speed. Note that the size of the chain has no effect on the ratio.

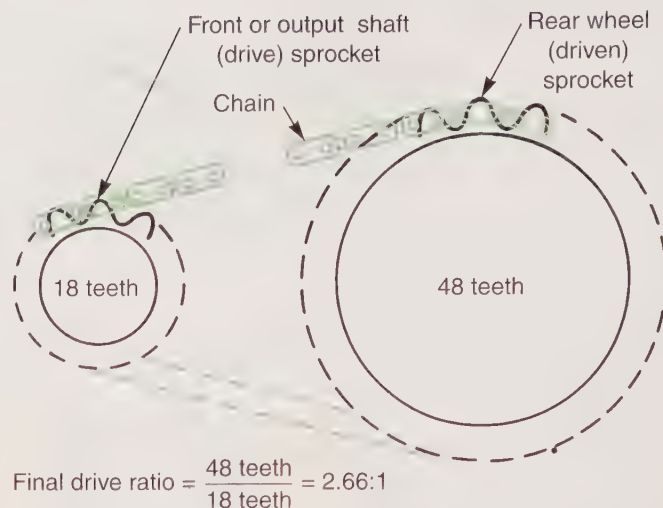


Figure 4-21. Chain drive ratios are figured in the same way as gear ratios. The number of teeth on the driven sprocket is divided by the number of teeth on the drive sprocket. The resulting figure is the ratio. The length of the chain has no effect on the ratio.

Chain Lubrication

Even the most efficient chains require lubrication. One advantage of chain drives is that they are usually enclosed. This way, they are kept lubricated, as well as protected from dirt and moisture.

There must always be some provision for chain lubrication. The chains used in vehicle drive trains are usually designed so they pass through a pool of oil, which collects in the bottom of the chain case. In other cases, oil is sprayed onto the chain through a calibrated oil hole.

Chain Inspection

A chain drive should be inspected whenever there is evidence of chain problems or when the chain is removed from the vehicle for any reason. Chain and sprocket wear usually shows up as a loose chain. A loose chain is hard on sprocket teeth. If the chain is loose, there is a good chance the sprocket is damaged. Always be sure to check both the chain and sprocket.

Sometimes a chain becomes so loose, it jumps off the sprockets. Usually the chain will become noisy before this happens. A worn, loose chain that is still in place will have too much slack. This will be more noticeable on the side that is not under tension. If the chain is removed from the sprockets, lay it sideways, as shown in **Figure 4-22**. Any noticeable sagging means the chain is worn out and should be replaced.

The sprockets should be checked for excessive wear or cracks. The tooth faces of roller chain sprockets may appear as hooked teeth. In extreme cases, even these hooks will be worn away. Sprocket problems often resemble gear problems. The tooth faces of silent chain sprockets will often show a series of indentations where the chain makes contact.

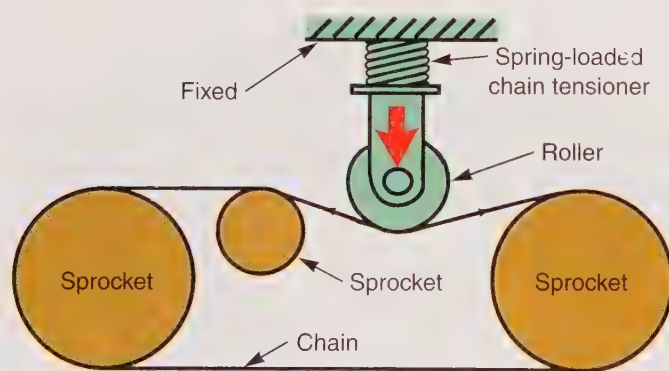


Figure 4-20. Like any mechanical part, chains and sprockets will wear. Wear makes the chain loose. A loose chain will be noisy and may jump off the sprockets. To keep the chain from becoming too loose, a chain tensioner is often used. Most tensioners are spring-loaded. A spring is compressed against the chain. This puts tension on the chain and takes up the slack.

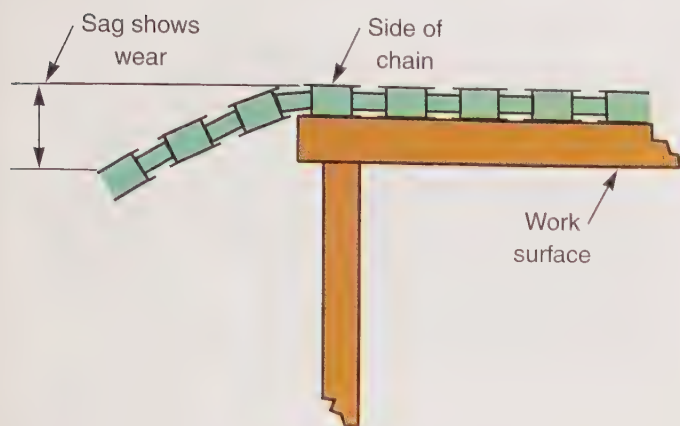


Figure 4-22. Chains that are in place should be checked for looseness. A removed chain may be checked on a workbench by laying the chain on its side and projecting it off the edge. A chain that sags even slightly should be replaced.

A worn or damaged sprocket should be replaced. The chain may be reused, in this case, depending on its condition. If a chain needs to be replaced, the sprockets should always be replaced along with it, as a set. Otherwise, the old sprocket may damage the new chain.

A problem encountered in chain drives is misalignment of sprockets. When chains are used, there is little room for misalignment, which is one of the disadvantages of chain drives. Misalignment will cause excessive chain and sprocket wear and noise. In extreme cases, the chain will jump out of engagement with the sprockets.

For proper alignment, sprocket shafts must be parallel. Distances between shafts on both front and back sides of the sprockets should be equal. Also, for proper alignment, the two sprockets must be in line with each other or fall in the same plane. This can be checked by connecting a straight edge across the flat surfaces of the sprockets.

Bearings

Bearings are used to reduce friction between rotating and stationary parts. Further, they guide and support rotating parts to prevent damage from misalignment or excessive clearances. The relationship between a rotating shaft, a stationary housing, and a bearing is shown in **Figure 4-23**.

This section discusses how bearings reduce friction and guide and support rotating parts. It also covers the many types of bearings, and inspection and service procedures.

Friction

When two objects rub together, resistance to movement arises between them. This resistance is friction. Friction is a part of everyday life. Often, it is useful. Friction between your shoes and the ground, an example of static friction, allows you to walk without falling. Friction holds assembled parts together. It prevents threaded parts from

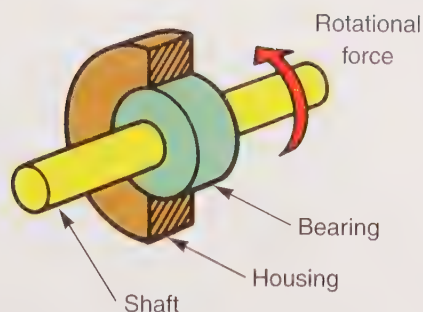


Figure 4-23. Note the relationship between rotating shaft, stationary housing, and bearing. The bearing ensures the shaft is properly aligned with the housing. It also serves as a buffer and incurs the wear, rather than the shaft or housing. This makes servicing easier and cheaper. (Federal Mogul)

unthreading and provides the holding power for press-fit parts. Friction is what makes a brake system work.

There are times when friction can be a handicap. Friction between a free turning part and a stationary part will turn power into heat and wear. Friction can be a severe problem in the drive train, where the rotating parts are moving at high speeds. In addition, drive train action often puts side loads on a shaft, subjecting one side of a stationary part to more friction. Bearings reduce friction by providing a slipping or a rolling surface between moving parts.

Types of Bearings

There are two major classes of bearings—friction and antifriction. **Figure 4-24** illustrates the two types. The **friction bearing**, or **plain bearing**, as it is sometimes called, is pressed into place and does not move. A rotating shaft slides around on the friction bearing surface. The **antifriction bearing** uses an assembly of balls or rollers contained within a housing where they are aligned and free to roll. The bearing is pressed into place; however, the one side (inner or outer) is free to move with the rotating member because of the rolling elements. This changes sliding, or kinetic, friction between the mating surfaces to rolling friction.

Friction Bearings

Friction bearings are used for supporting rotating shafts. A rotating shaft slides around the supporting surface of the bearing, which is stationary. Friction bearings are one-piece or two-piece designs. One-piece bearings are solid sleeves and are often called bushings. They are usually pressed into place. One-piece friction bearings are used in many places in the drive train. Two-piece bearings are inserted in stationary drive train parts before they are assembled around the rotating shaft. The most common place where two-piece bearings are used is in engine connecting rods and crankshafts. In engines they are called bearing inserts. Two-piece bearings are only occasionally used with drive train components.

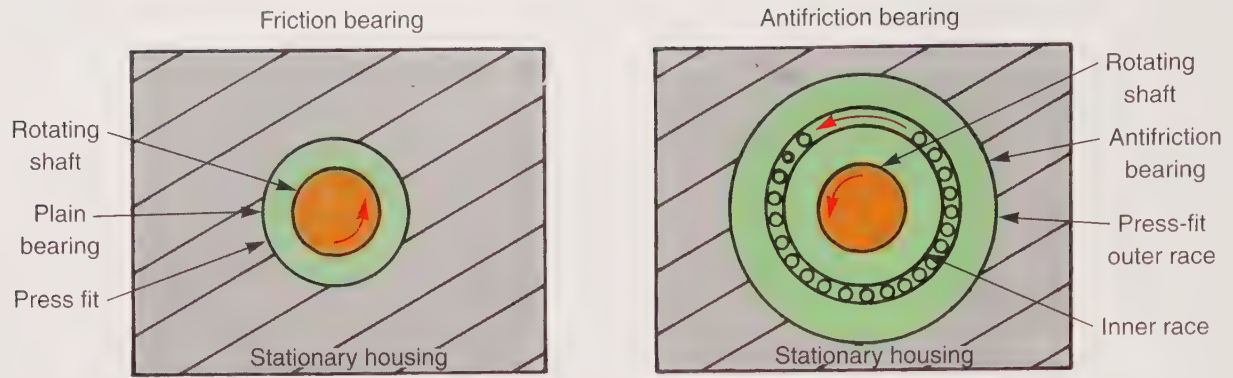


Figure 4-24. The two main types of bearings are shown. Note that sliding friction is seen in the friction bearing, while rolling friction is seen in the antifriction bearing.

Friction bearing material

Friction bearings are composed of many materials. Most bearings used in transmissions are made of a steel shell with a coating of a soft metal such as copper, brass, lead, or aluminum. Sometimes babbit metal, which is an alloy of tin or lead, copper, and antimony, is used for the coating.

Friction pilot bearings in the clutch assembly used to support transmission input shafts, and some bearings used in transmissions, are solid brass or bronze. One thing is true about any friction bearing, no matter what its composition, it is always designed to wear before the shaft metal. This is done so that the bearing, which is relatively cheap, will wear out instead of the expensive shaft.

Friction bearing lubrication

A rotating shaft can contribute to friction through two types of loads—radial and axial. **Radial loads** are perpendicular to the axis of rotation. **Axial, or thrust, loads** are parallel to the axis of rotation. To reduce friction from these loads, the bearing must be lubricated.

For proper bearing lubrication, the shaft and bearing must be separated entirely by a film of lubricant, **Figure 4-25**. When enough lubricant is present, the sliding action takes place in the lubricant between the shaft and the bearing; the shaft rides on the film.

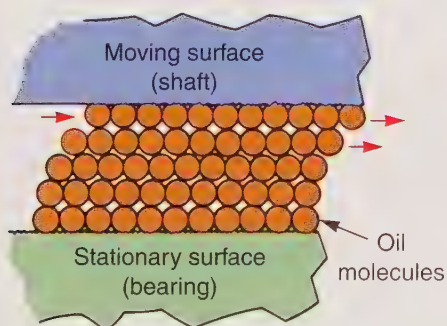


Figure 4-25. A film of oil between two surfaces can act as a bearing. Oil molecules serve as tiny ball bearings. The oil film is what makes the use of friction bearings feasible. (Federal Mogul)

To accommodate the bearing lubricant, a clearance is needed between the shaft and bearing. An **oil clearance**, **Figure 4-26**, must allow the lubricant to enter and circulate properly. If the clearance is too tight, the lubricant cannot form an adequate surface between the mating parts. If it is too loose, the lubricant will leak out too quickly to maintain the surface separation. The shaft and bearing are said to have a **running fit** when the oil clearance is sufficient to enable parts to turn freely and receive proper lubrication.

The lubricant itself may be a type of oil supplied by pressure, splash, or immersion. It may be a heavy grease applied periodically. Friction bearings used in automatic transmissions are often supplied with oil from the transmission oil pump. Bearings used in standard transmissions are lubricated by splash from the turning gears. Friction pilot bearings in the clutch assembly are greased only when the clutch is serviced.

Most friction bearings will have slots and grooves for lubricant. The grooves usually run the entire length of the bearing surface. They allow the lubricant to be picked up and evenly distributed around a moving shaft. **Figure 4-27** shows a number of friction bearings. Notice the grooves and slots in these bearings.

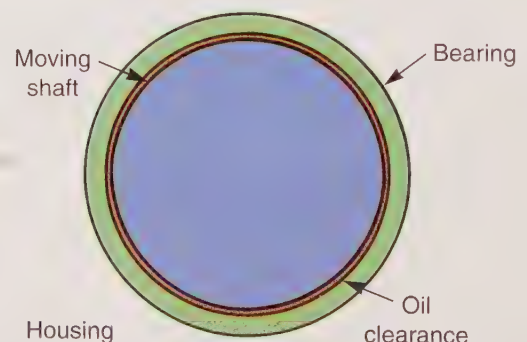


Figure 4-26. The oil clearance between a bearing and a shaft is usually a few thousandths of an inch. This clearance must be loose enough to allow the oil to reach the bearing and shaft surfaces. However, it must not be so loose that the oil leaks out too quickly. (Federal Mogul)

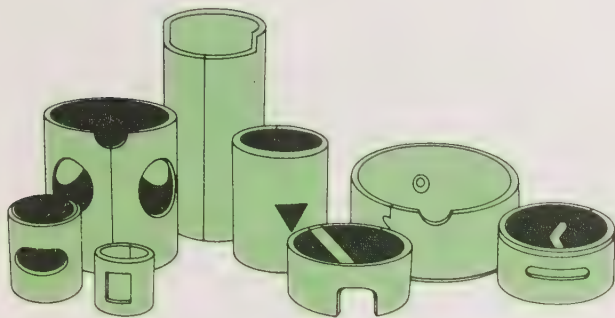


Figure 4-27. An assortment of friction bearings showing grooves and slots for lubrication. (Federal Mogul)

Friction bearing removal

Bushings and sleeves, friction bearings of one-piece construction, are press fit into position. There are a couple ways to go about removing them. The best way is to use a puller made for the particular bearing. The puller is secured to the bearing. Applying pressure will remove the bearing from the housing.

A different method of bearing removal can be used when the bearing housing is a blind hole—that is, open on one side and blocked off on the other. An example of this is the clutch pilot bearing. To remove a bearing from a blind hole, pack or fill the area behind the bearing with heavy grease. Insert a shaft that is of the same diameter as the bearing opening into the bearing. Put on eye protection and strike the exposed end of the shaft with a hammer. The hammer force will transfer to the grease, and the region behind the bore will become pressurized. This pressure will be applied to the bearing, and the bearing will be forced from the bore.

A cape chisel or a round-nose cape chisel is an ideal tool for removing small bushings where both ends are accessible. A pin punch is another tool that can be used. Where applicable, these tools can be used to remove sleeves and insert bearings as well. Always use care to avoid damaging the bearing housing.

Friction bearing inspection

Whenever a drive train part is disassembled, the bearings should be closely inspected. Clean the bearings thoroughly before inspection. Use a solvent that will not damage or coat the bearings.

During inspection, check for wear and damage. A normally worn bearing will have smooth contact surfaces. Bearings that are to be reused should be checked for proper size. Often a bearing will look good but will be worn excessively. Bearing clearances often measure only up to a few thousandths of an inch or several hundredths of a millimeter.

One quick way to check a friction bearing is to place it onto the shaft on which it rides. If the fit feels loose, the bearing, and possibly the shaft, is worn. This method depends on your knowing what a loose bearing fit feels like. It is hard to tell without experience.

If you are not sure, check the actual dimension of the bearing's inside diameter using a caliper or other such instrument. If the bearing has excessive clearance in one area only, it has been subjected to heavy loads on one side. Check that the shaft is not bent or misaligned. Any bearing with excessive clearance should be replaced.

In many cases, when the bearing is replaced, the shaft might also have to be replaced. Do not assume that replacing the bearing will solve the problem. Proper operation of the assembly depends on both the bearing and the shaft. Always check the shaft where it mates with the bearing. If there is no obvious damage, use a micrometer or sliding caliper to check for proper diameter and taper. Check the shaft in several places.

Another problem to look for is scoring of the bearing. Scoring will appear as scratches or ridges partially or totally inscribed about the bearing surface. Scoring is usually caused by lack of lubrication or by abrasive particles in the lubricant. If the bearing is badly scored, the shaft is probably also damaged.

A bearing that has been in use for some time may have pitting or even large craters in its surface. Pitting starts with dirt or water in the lubricant. Over time, large pits or craters can develop.

Sometimes, a missing ground strap between the engine and car body can cause craters. The engine's electrical components will ground through the drive train. This electrical action will cause metal transfer, leading to pitting.

Sometimes, a friction bearing will be operated without lubrication or under other abusive conditions. This can lead to severe bearing damage. Bearings may overheat, spin in their housing, or weld themselves to the shaft. A sign of a bearing that has been subjected to overheating is a change in the material's color. Indications of spun or welded bearings will usually be obvious. In many cases, the shaft or housing must also be replaced or repaired.

Friction bearing installation

Bearing drivers are made to closely fit into a bearing. The bearing will bottom against a slightly larger area on the driver. Pressure on the driver is transmitted to the bearing, and the bearing is forced into its housing.

Bearings should be installed with the proper-size driver, preferably on a hydraulic press. If a press is not available, some bearings can be hammered into place using a driver to avoid part damage. Strike the driver with a hammer. Do *not* strike the bearing with the hammer. Also, attempt hammering only if the proper-size driver is available.

The bearing should be installed carefully. If the bearing has any oil supply holes, line them up with the oil holes in the housing for the bearing. Make sure the bearing enters the housing bore squarely and does not become cocked. A poorly installed bearing will quickly destroy itself and the shaft it supports.

After the bearing is installed, additional service may be required. Some bearings will require reaming and honing to widen and smooth the bearing inside diameter to fit the mating shaft. Some bearings must be staked. This

involves taking a punch to the bearing surface, which produces a raised dimple on the side of the bearing against the housing. This action locks the bearing in place and keeps it from spinning or slipping out of position. After reaming, honing, or staking, the bearing should be thoroughly cleaned.

Replacement bearings should be checked to ensure they have the proper clearance with the shaft. Before reassembly, that is, before inserting the shaft into the bearing, lightly lubricate the bearing surface. Use the same kind of lubricant that the bearing will have during normal operation. This will ensure adequate lubrication the first time a load is placed on the bearing. If the bearing is only lubricated during service (a clutch pilot bearing, for example), be sure to apply the proper amount of grease before reassembly.

Antifriction Bearings

Antifriction bearings contain rolling elements that operate within a housing made up of one or two pieces of metal. The rolling elements can be balls or rollers. In general, the pieces of the housing are called **races**. For conical antifriction bearings, the races are sometimes called cones. For long life, all of these parts are made of heat-treated, high-strength steel.

A typical antifriction bearing with an inner race, an outer race, and a rolling element is shown in **Figure 4-28**. Note that antifriction bearings do not always have both an inner and outer race to contain the rolling elements. Sometimes, one of these is omitted. Then the elements are in direct contact with the mating surface.

In addition to rolling elements and races, many antifriction bearings contain a cage to keep the rolling elements in position. Also, some bearings are prelubricated and have seals to keep the lubricant in and to keep dirt and moisture out. The placement of seals is shown in **Figure 4-29**.

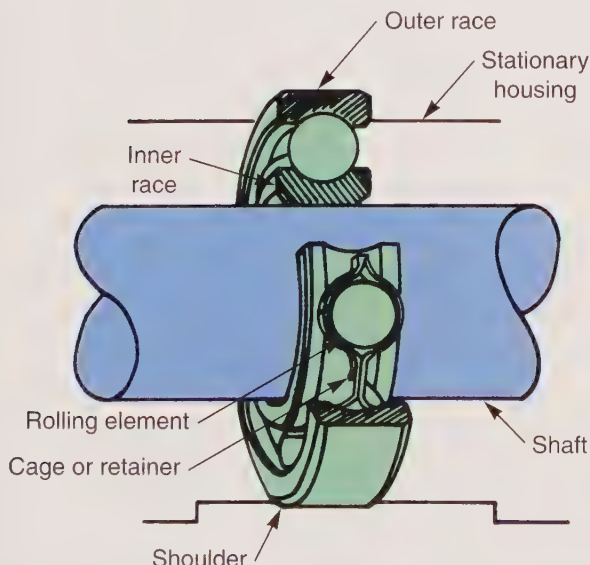


Figure 4-28. A typical antifriction bearing. Note the three major parts—inner race, outer race, and rolling element.

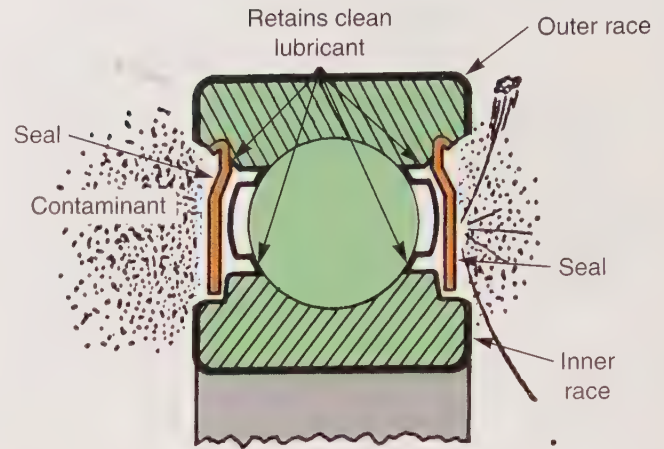


Figure 4-29. Some bearings have a seal, as shown in this partial sectional view of a ball bearing. The seal serves to keep bearing lubricant in and dirt and moisture out. Bearings inside of a transmission, transaxle, or rear axle assembly will not have a seal.

Antifriction bearings may be pressed or slipped into position—onto a shaft, for example, or into a stationary housing. Frequently, the bearing is pressed onto the shaft, and then the shaft and bearing are slipped into place in the stationary housing. In some cases, such as rear axle pinion gear bearings, the bearing is pressed into the stationary housing.

The advantage of the antifriction bearing is that it uses a rolling motion, rather than a sliding motion like the friction bearing. The rolling motion produces less friction. The antifriction bearing is usually used where rotating parts are highly stressed or where it is difficult to supply adequate amounts of lubricant. The antifriction bearing is more efficient than the friction bearing, but it is more expensive. Sometimes, however, size, clearance problems, or the back-and-forth movement of the shaft prevent the use of an antifriction bearing.

Types of antifriction bearings

The two major types of antifriction bearings are ball bearings and roller bearings, **Figure 4-30**. Ball bearings are used for clutch throwout bearings, which are used for clutch release. They are also used for pilot bearings and in some transmissions and transaxles. Roller bearings of various types are used as pilot bearings and also in transmissions and rear axle assemblies. Tapered roller bearings, needle bearings, and thrust bearings are all variations of the roller bearing.

Ball bearings, although they vary in size, are used in automotive drive trains and are all of the same basic design; however, methods of lubrication vary. Clutch throwout bearings and some rear axle bearings are greased by the manufacturer and are not intended to be regreased. Ball bearings used in other parts of the drive train are lubricated by oil splashed from other moving parts.

As mentioned, there are several types of **roller bearings**: straight roller bearings, tapered roller bearings, needle

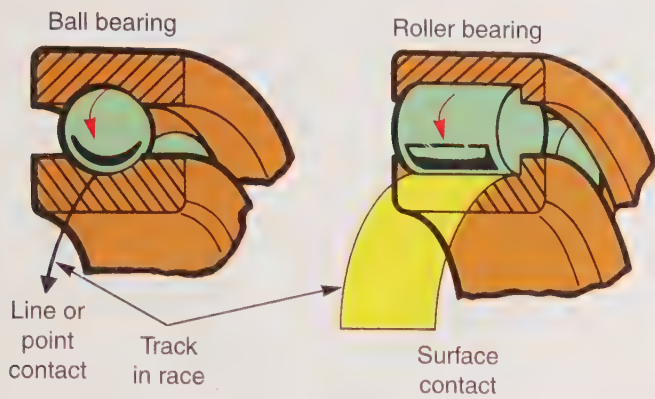


Figure 4-30. Two types of antifriction bearing—ball and roller—are shown. (Federal Mogul)

bearings, and thrust bearings. **Straight roller bearings** are used for axle bearings in rear axle assemblies, **Figure 4-31**. They are also used in manual and automatic transmissions. This type of bearing usually comes as a one-piece unit.

A **tapered roller bearing** is shown in **Figure 4-32**. Rollers of this bearing assembly are tapered. The outside diameter of the inner race (cone) and the inside diameter of the outer race (cup) are tapered also to fit the rollers. The assembled bearing, however, including its inside diameter, is cylindrically shaped. Tapered roller bearings are useful for heavy loads. They are used in rear axles and also in front drive axles.

Needle bearings, **Figure 4-33**, are another type of roller bearing. Needle bearings perform the same function as other roller bearings, but their diameter is much smaller in relation to their length. Needle bearings have tiny rollers that resemble needles, hence, the name needle bearing.

Thrust bearings are flat, disc-shaped bearings that resemble washers, **Figure 4-34**. Thrust bearings are made up of needle rollers. The rollers are arranged radially. This

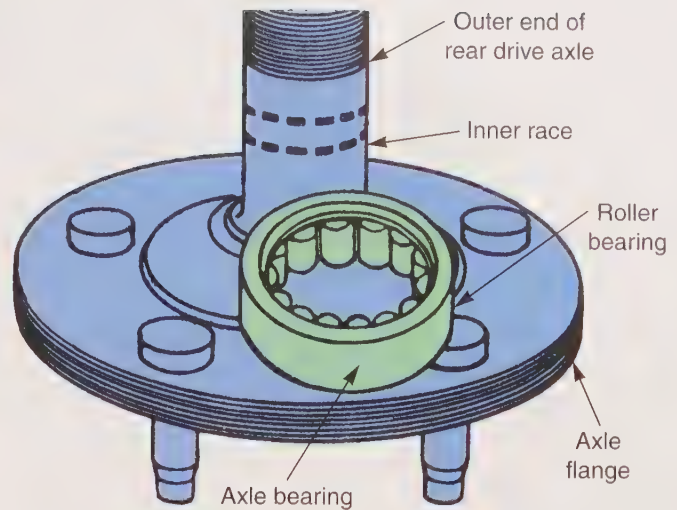


Figure 4-31. An example of a straight roller bearing. Notice that the bearing shown here has only an outer race and that the axle shaft functions as the inner race. The rolling elements fit right up against the shaft. (Ford)

means they radiate out along imaginary lines projected from a center point. This kind of bearing is sometimes called a **Torrington bearing**.

Bearing load factors

Antifriction bearings can be subjected to radial loads and thrust loads, **Figure 4-35**. Applied radial loads are directed perpendicular to a shaft's rotational axis. Thrust loading is directed parallel to the axis. Thrust loading is caused by the back-and-forth movement of the shaft. The design of helical and bevel gears inherently creates thrust loads, which must be compensated for in bearing design. In some cases, such as at the pinion shaft of a rear axle assembly, the bearings are preloaded to reduce the

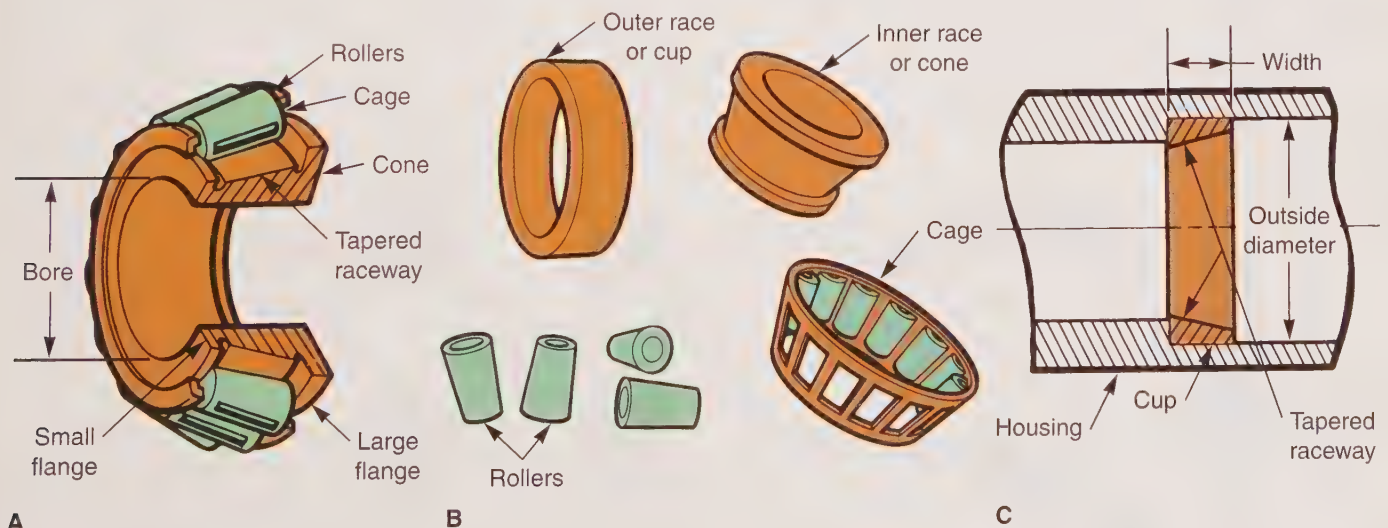


Figure 4-32. Tapered roller bearing. A—This sectional view of an assembled tapered roller bearing shows the bearing with the outer race removed. B—This shows various parts of a tapered roller bearing. C—This sectional view shows the outer race, or cup, installed in a housing.

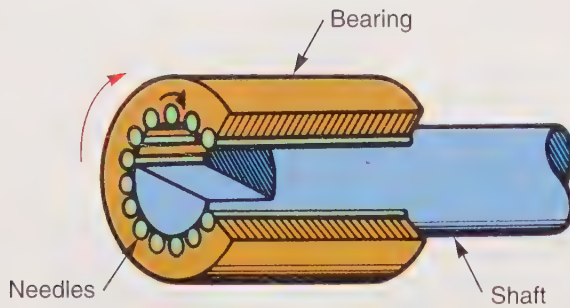


Figure 4-33. The rollers of a typical needle bearing are longer and thinner than those used with other roller bearings. Note that the bearing shown has only a single race.

deflection of parts and minimize thrust variation. Most bearing loads are combination loads, which are the result of both thrust and radial loads.

Ball and roller bearings are affected differently by loads. The ball bearing absorbs both thrust loads and radial loads on the ball surface. The straight roller bearing absorbs radial loads on the rolling surface, and minor thrust loads are absorbed on the sides of the rollers. The tapered roller bearing is designed to absorb both radial loads and thrust loads on the roller surfaces.

Applied loads will not be perfectly distributed about the bearing. Several factors can cause loading to be greater on one side or another. Gravity is a more obvious factor. Another is the manufacturing tolerances of gears and shafts—the fact that they are not perfectly round or symmetrical. Helical gears too, by their design, will cause loading to be greater on one side. These conditions will cause the bearing elements to be alternately loaded and unloaded as the shaft rotates. **Figure 4-36** depicts this action. Loading intensity is illustrated by the shading of the bearings—the darkest being the point of greatest intensity. In conclusion, the bearing must be manufactured to withstand not only heavy loads, but also the effects of changing loads.

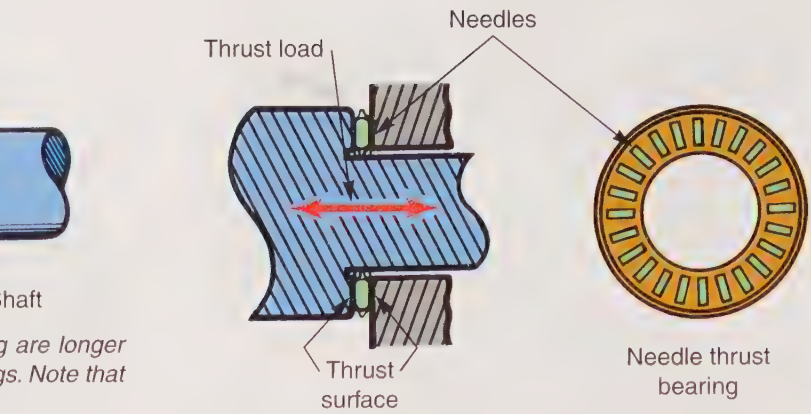
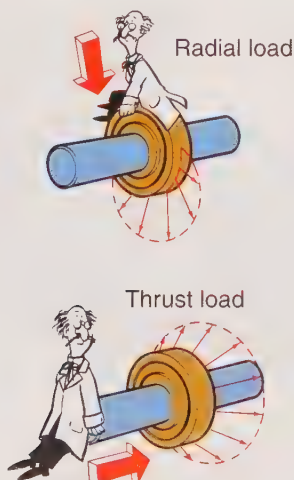


Figure 4-34. A thrust bearing using needle rollers. The needles are arranged radially; their axial centerlines radiate outward from a center point. (Federal Mogul)

Bearing servicing precautions

Whenever servicing antifriction bearings, there are some special precautions that you must be aware of and take:

- ☐ Always wear eye protection when removing or installing a bearing.
- ☐ Do *not* apply excessive force to a bearing or shaft during removal or installation.
- ☐ Do *not* apply any force through the rolling elements of an antifriction bearing. Only apply force to the press-fit side of a bearing. The bearing could be damaged or could burst and cause injury.
- ☐ Never spin a bearing with compressed air. The rolling elements could be thrown out with explosive force and severely hurt you or someone else. Mechanics have been killed by using compressed air to spin bearings.

Antifriction bearing removal

Some bearings are held to shafts by snap rings or by large nuts that thread onto the shaft. In these cases, bearing removal is simple. The snap ring or nut is removed, and the

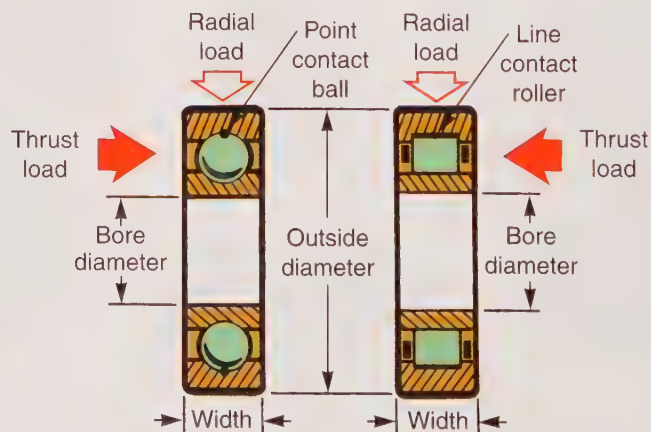


Figure 4-35. Two types of loads placed on a bearing are radial and thrust. The two loads acting on a bearing at the same time may be referred to singly as a combination load. Most drive train bearings are subjected to combination loads. (Federal Mogul)

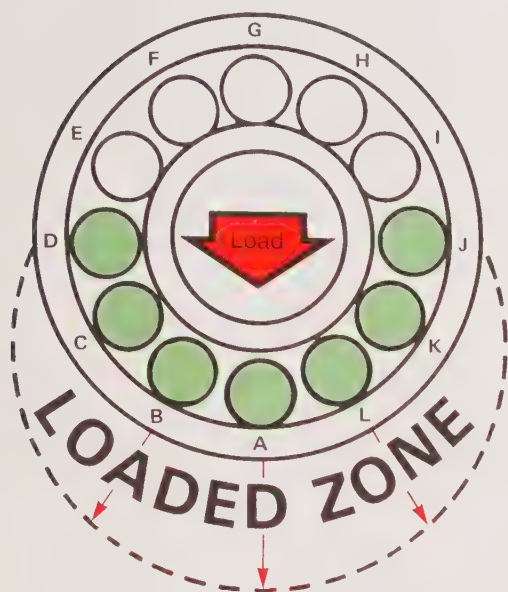


Figure 4-36. Complicating the bearing loading process, bearing loads vary according to gravity and shaft tolerances. Bearing rollers are alternately loaded and unloaded as the shaft rotates. (Federal Mogul)

bearing is slid from the shaft. In other cases, the bearing is pressed on, and special methods must be used to remove it.

The best way to remove a pressed-on antifriction bearing from a shaft that has not been removed from its installation is to use a bearing puller. Some pullers are made for a particular bearing. Others are universal designs that can be used on almost any bearing. These pullers have adjustable jaws that can be tightened around the bearing. Using a puller, the bearing can be forced from its shaft.

An ideal way to take a bearing off a shaft that is removed from a vehicle is to use a hydraulic press. A support is placed under the bearing, and pressure is applied to the shaft to press the shaft from the bearing. Remember! Pressure should only be applied to the press-fit race. Applying force through the rolling elements could damage the balls, rollers, or races. Refer to **Figure 4-37** for examples of proper and improper bearing removal.

Some bearings are press fit into a housing instead of around a shaft. A brass drift can be used to drive the race from the housing. Look for a notch cut into the shoulder of the outer race, and carefully apply the drift to it to remove the bearing.

Sometimes, a bearing retainer, which is a force-fit metal ring or plate, must be removed before removing a bearing. This situation applies to some rear axle bearings. The retainer is removed with a chisel or torch—carefully, to avoid damaging the shaft. In some cases, it is possible to cut the bearing from the shaft with a cutting torch. The torch must be used with caution to prevent overheating or otherwise damaging the shaft. If there is any way to avoid using a torch, do so.



Warning: Wear eye protection when cutting off a retainer plate.

Antifriction bearing inspection

Bearings should be thoroughly cleaned before inspection. Often, what appears to be a bearing defect is dirt that has collected on the bearing during disassembly. At other times, actual bearing defects are hidden by dirt or sludge. If you are cleaning a bearing with compressed air, always hold both races so the bearing does not spin. *Never spin bearings with compressed air.*

After cleaning, rotate the bearing by hand as shown in **Figure 4-38**. Note if there are any places where you feel

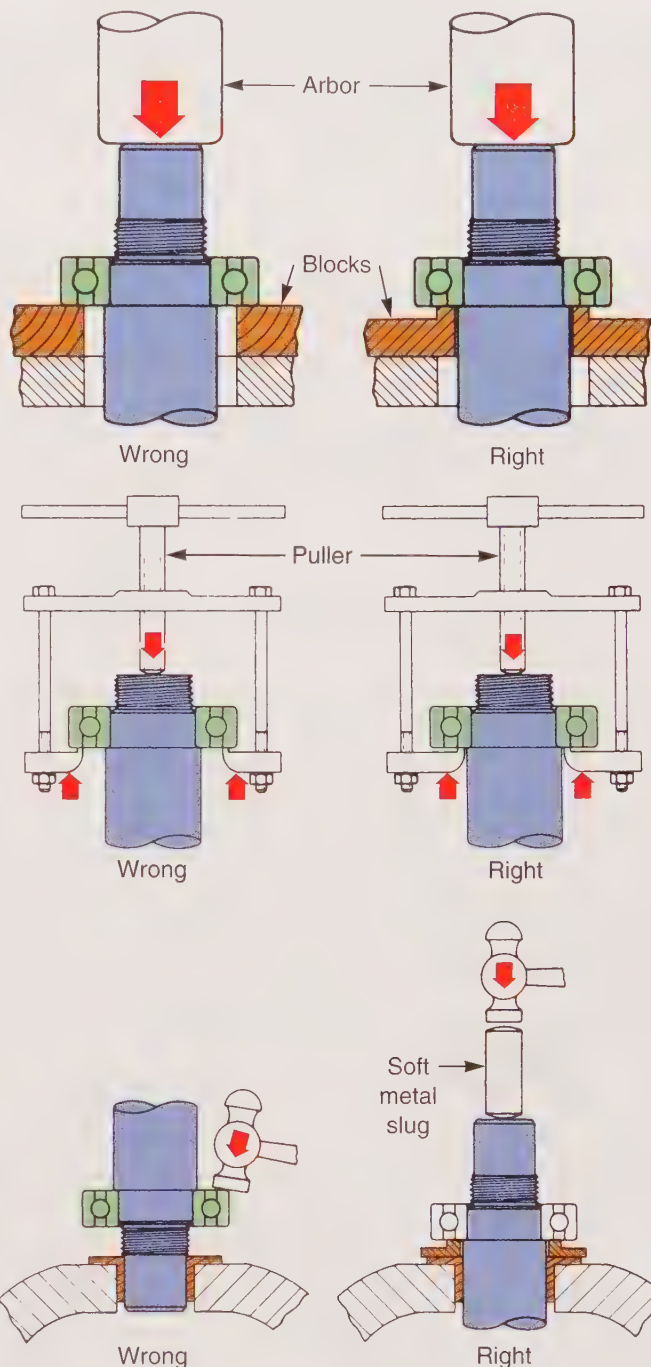


Figure 4-37. Different methods of bearing removal. Do you see the difference between right and wrong ways of removal in each drawing? (FAG Bearings)

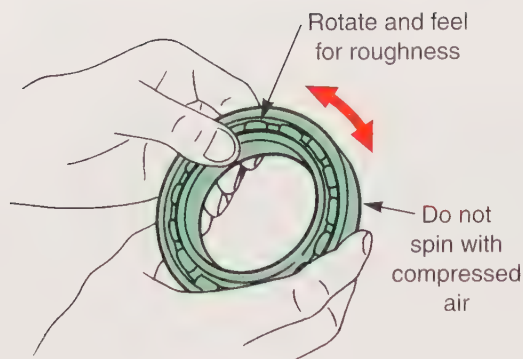


Figure 4-38. During inspection, hold clean bearing as shown and rotate outer race by hand. Do not use compressed air to inspect. An unloaded bearing spun at high speeds can explode! (Nissan)

roughness or binding. If you find any problems, replace the bearing.

Visually inspect the bearing for signs of wear and damage, including conditions of scoring, overheating, and corrosion. Bearings may show signs of extreme wear or damage due to problems of overloading and lack of lubrication. Spalling and brinelling are indications of these problems, **Figure 4-39**. Check for a bent or otherwise damaged cage. Cage damage is usually caused by careless installation.

Identifying replacement bearings

It is very difficult to match bearings by a visual inspection. It is, therefore, important to make sure the replacement bearing you get is the bearing you need. If the old

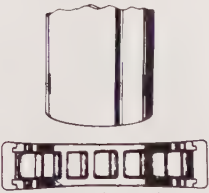
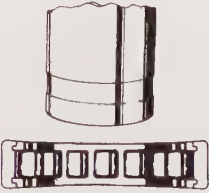
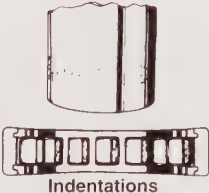
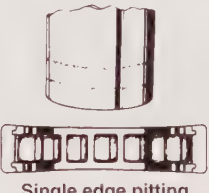
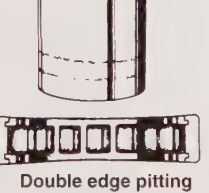
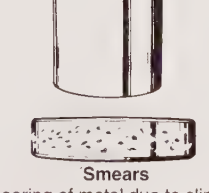
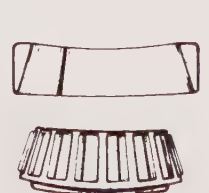
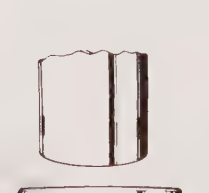
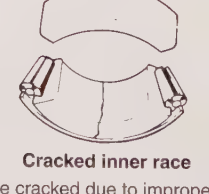
 Wear (minor) Light pattern on races and rollers caused by fine abrasives. Clean all parts and housings. Check seals and replace bearings if rough or noisy. Replace shaft if damaged.	 Wear (major) Heavy pattern on races and rollers caused by fine abrasives. Clean all parts and housings. Check seals and replace bearings if rough or noisy. Replace shaft if damaged.	 Indentations Surface depressions on race and rollers caused by hard particles or foreign material. Clean all parts and housings. Check seals and replace bearings if rough or noisy. Replace shaft if damaged.	 Single edge pitting Flaking of surface metal resulting from fatigue, usually at one edge of race and rollers. Replace bearing – clean all related parts. Replace shaft if damaged.
 Double edge pitting Flaking of surface metal resulting from fatigue, usually at both edges of race and rollers. Replace bearing – clean all related parts. Replace shaft if damaged.	 Smears Smearing of metal due to slippage. Slippage can be caused by poor fits. Lubrication, overheating, overloads or handling damage. Replace bearings, clean related parts and check for proper fits and lubrication.	 Brinelling Surface indentations in raceway caused by rollers either under impact loading or vibration while the bearing is not rotating. Replace bearing if rough or noisy.	 Cage wear Wear around outside diameter of cage and roller pockets caused by abrasive material and inefficient lubrication. Check seals and replace bearings.
 Heat discoloration Heat discoloration can range from faint yellow to dark blue resulting from overload or incorrect lubricant. Excessive heat can cause softening of races or rollers. To check for loss of temper on races or rollers a simple file test may be made. A file drawn over a tempered part will grab and cut metal, whereas, a file drawn over a hard part will glide readily with no metal cutting. Replace bearings if overheating damage is indicated. Check seals and other parts.	 Stain discoloration Discoloration can range from light brown to black caused by incorrect lubricant or moisture. Reuse bearings if stains can be removed by light polishing or if no evidence of overheating is observed. Check seals and related parts for damage.	 Fretage Corrosion set up by small relative movement of parts with no lubrication. Replace bearing. Clean related parts. Check seals and check for proper fit and lubrication. Replace shaft if damaged.	 Misalignment Replace bearing and make sure races are properly seated. Replace shaft if bearing operating surface damaged.
			 Cracked inner race Race cracked due to improper fit, cocking, or poor bearing seats.

Figure 4-39. Refer to the above to learn about common antifriction bearing defects and their causes. (General Motors)

bearing has a part number, compare it with the number of the replacement bearing, **Figure 4-40**. If the old bearing does not have a number, or the number cannot be read, consult an appropriate parts catalog to ensure that the bearing is correct for the make and model of the vehicle you are working on. In some cases, you may need to obtain the serial number of the vehicle or of a particular component (transmission, rear axle, etc.).

Storing bearings

Cleanliness is vital to the successful operation of anti-friction bearings. Bearings should be left in their original wrappings until just before installation. If a bearing must be greased before installation (this usually applies to bearings of front drive wheels, clutch throwout bearings, etc.), pack the bearing in a manner similar to that shown in **Figure 4-41**. The grease must reach all of the voids, or spaces, in the cage. Be careful not to drop any bearings; since the hardened steel is brittle, it may chip or develop a shock crack.

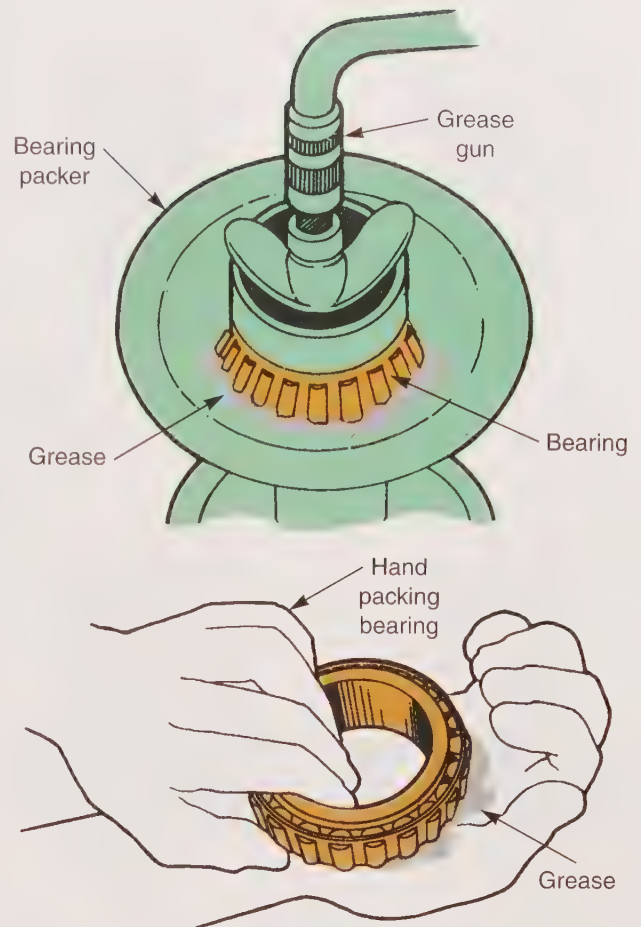
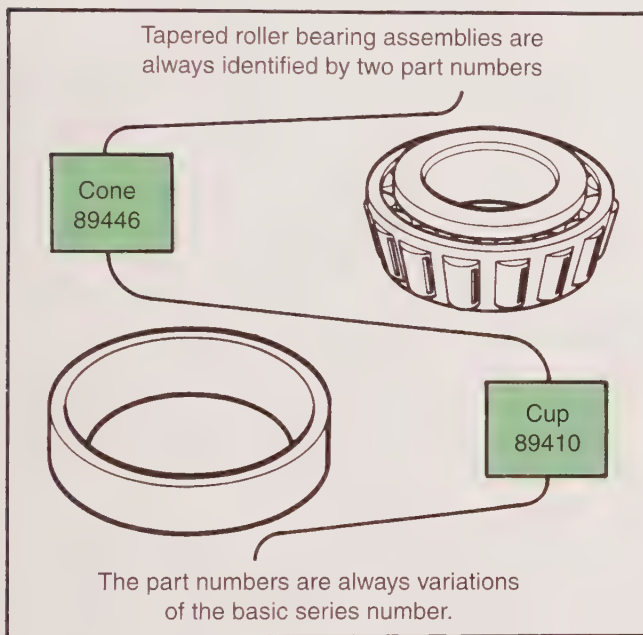


Figure 4-41. Antifriction bearings (where applicable) should be carefully packed with grease as shown. Bearings can be packed with a machine made for the purpose or by hand.

Antifriction bearing installation

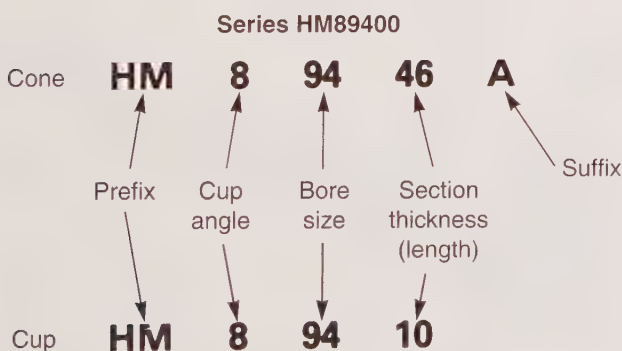
The best way to press a bearing on is with a bearing driver and a hydraulic press. A driver of the proper diameter is selected to fit the bearing. Pressure on the driver from the hydraulic press is transferred to the bearing, and the bearing is forced onto the shaft.

If a hydraulic press is not available or cannot be used, some antifriction bearings can be driven into place by tapping on the race to be press fit. Remember not to hammer on the free race when installing a bearing. This will cause damage to the rolling elements and races and can cause injury.

When press fitting a bearing, watch closely to ensure it is not being cocked or pressed in too far. If the shaft has a shoulder, the bearing should firmly bottom on the shoulder. Also, make sure dirt or other debris is removed from the bearing before installation. Refer to **Figure 4-42** for examples of proper and improper bearing installation.

If a shaft is too large, a bearing can be heated and expanded somewhat. This might enable the bearing to be dropped into place over the shaft. If you decide to use this method, make sure you do not overheat the bearing. Doing so will destroy the properties of the metal and ruin the bearing.

Figure 4-40. Always try to identify the part number of the original bearing before ordering replacements. An example is shown here. If the number is missing, you will need to gather information about the vehicle to obtain a replacement part. (Federal Mogul)



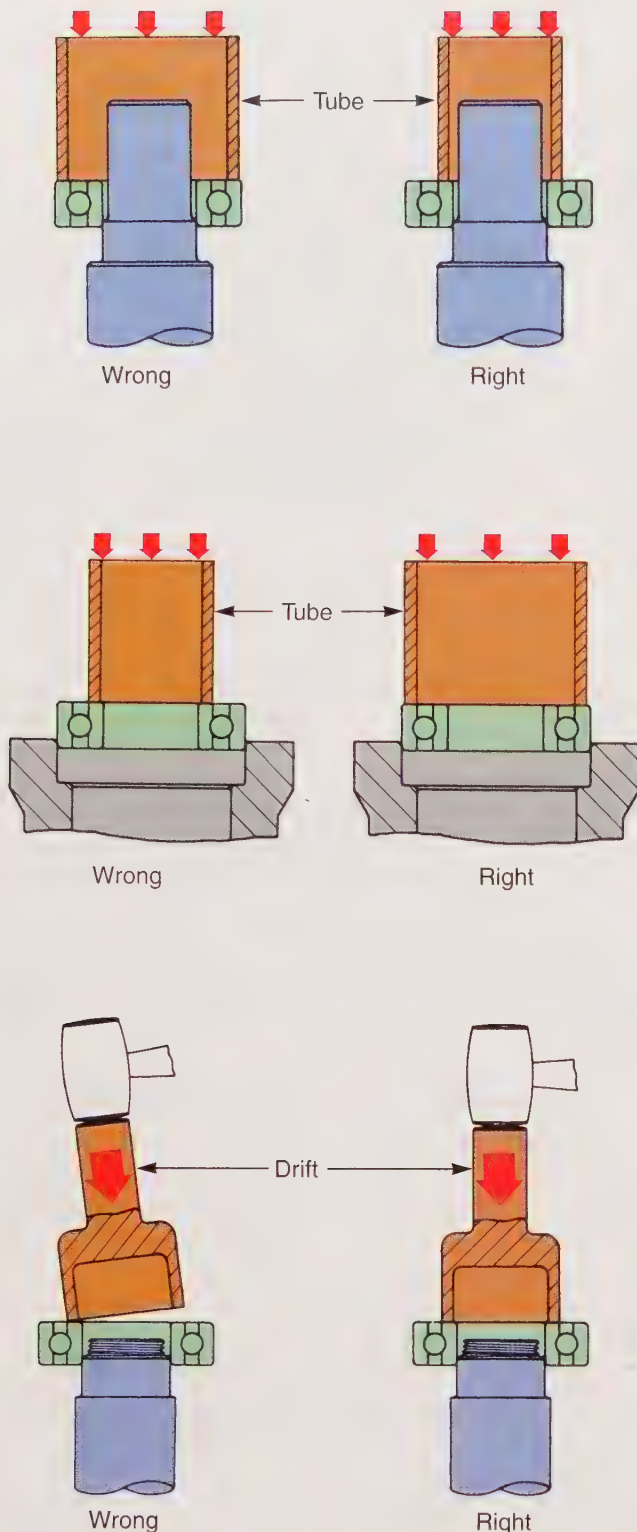


Figure 4-42. When installing bearings, keep in mind that force should never be applied through the rolling elements. Also, when pressing a bearing onto a shaft or into a housing, always make sure the bearing is going on or in straight. Analyze the diagrams showing different methods of installing bearings. Do you see the difference between right and wrong ways of installation in each drawing? (FAG Bearings)

Just as a bearing can be expanded by heating, it can also be shrunk by cooling. Therefore, if a bore is too small for a bearing, you can try chilling the bearing in a freezer. This may shrink it just enough to allow installation into the bore.

After the bearing is installed, check it for proper operation and alignment. Some bearings, like pinion and front axle bearings, must be preloaded or adjusted so they are under mild pressure. This is done to prevent bearing looseness. When bearings must be preloaded, follow the manufacturer's procedures exactly. Bearing preloading is discussed again in Chapter 16 and Chapter 17.

Related Components

Many components are used with gears and bearings in the drive train. Some of these are explained below.

Thrust Washers

Thrust washers are used between the end of a rotating shaft and a stationary housing or between two rotating shafts. They prevent excessive axial, or back-and-forth, shaft movement by limiting the amount of **end clearance**, or the distance between the two parts. This type of shaft movement is often called **endplay**.

Figure 4-43 is a typical thrust washer. Like friction bearings, thrust washers are made of a metal that is purposely softer than the parts against which they operate. Most thrust washers have a key or tab extension. This is to lock the washer to one component so that all wear occurs on the side contacting the other component. The grooves in the thrust washer allow lubricant to flow between the contact surfaces of the washer and rotating part. Note that Torrington bearings are often used as thrust washers.

Most thrust washers are replaced when end clearance becomes too large. Thrust washers for some drive train units are available in different thicknesses. This way, improper endplay in the unit can be corrected by selecting a thicker or thinner washer.

Retainer Plates

Retainer plates are used to hold gears and bearings in position. They are attached to a stationary housing with bolts, machine screws, or snap rings. Most retainer plates have a center hole for a shaft to pass through.

Retainer plates are used on most manual transmissions. The front bearing retainer is an example. Retainer plates are also used on some drive axles. They attach to the ends of the axle housing and keep the bearing and axle from moving outward, slipping out of the axle housing. See **Figure 4-44**.

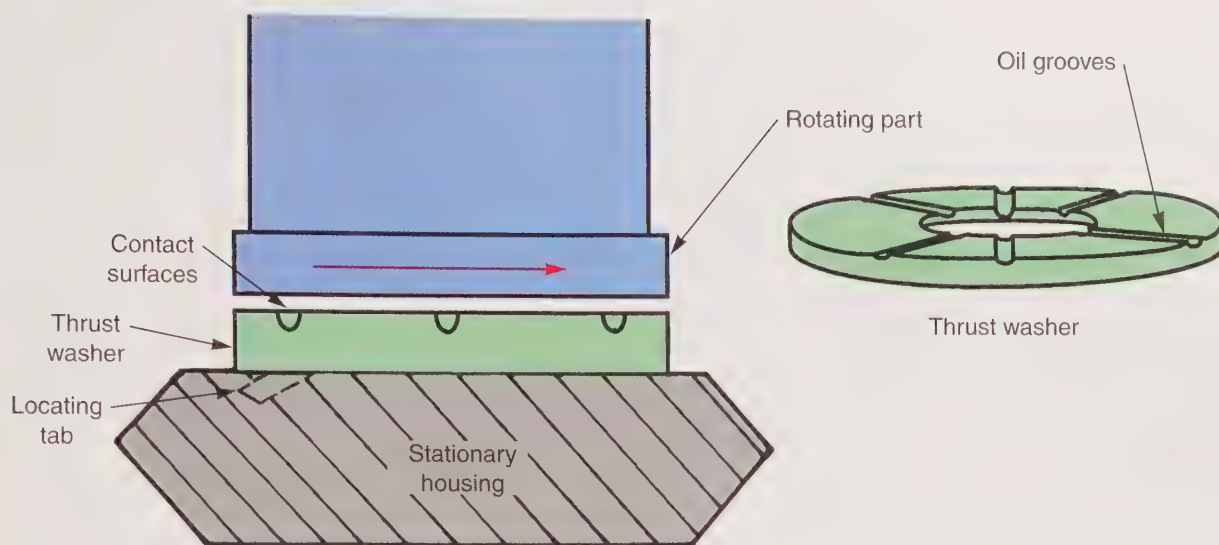


Figure 4-43. Thrust washers are installed between two parts where there is relative rotational motion between the two. Thrust washers keep back-and-forth movement of shafts to a minimum. This is a concern when using helical gears, which tend to cause this sort of movement. Thrust washers also reduce thrust caused by friction and wear.

Collars

Collars are another type of retainer. These are steel rings used to hold gears or bearings on shafts, as shown in **Figure 4-45**. Collars are usually used where space is too limited to allow a different kind of retainer. They are usually a press fit.

Collars are most often removed with a chisel, which is used to split the part open. There are other ways to remove a collar, but they usually expand and distort the collar. A collar, in any case, should never be reused. If it is not destroyed in the removal process, it will most likely be distorted and not fit properly.

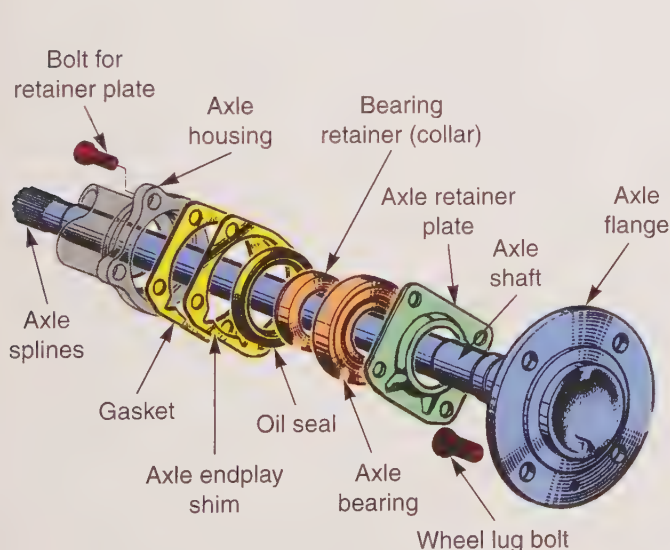


Figure 4-44. The retainer plate in this assembly keeps the bearing and axle from coming out of the axle housing. (Toyota)

Splines

A **spline** is a type of slot that is cut into a shaft or other part. The slot runs longitudinally, or lengthwise, to the axis of rotation. A spline may be straight, running parallel to the axis of the shaft or part, or it may be a spiral, running at an angle. A **splined shaft** will have many equally spaced, parallel splines. Splines can be internal or external, **Figure 4-46**. Internal splines of one component are designed to mate with external splines of another component. The two components, then, rotate as a unit.

Splines serve the important purpose of allowing two parts to move back-and-forth in relation to each other,

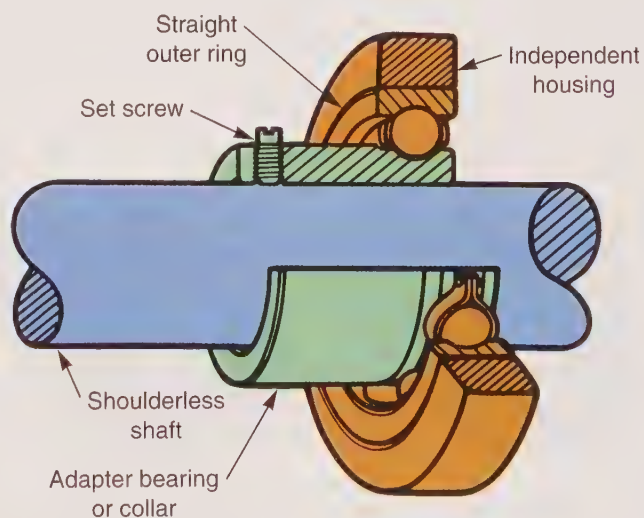


Figure 4-45. Collars are generally used to retain bearings on shafts, as shown here. They are also sometimes used to retain gears. (Federal Mogul)

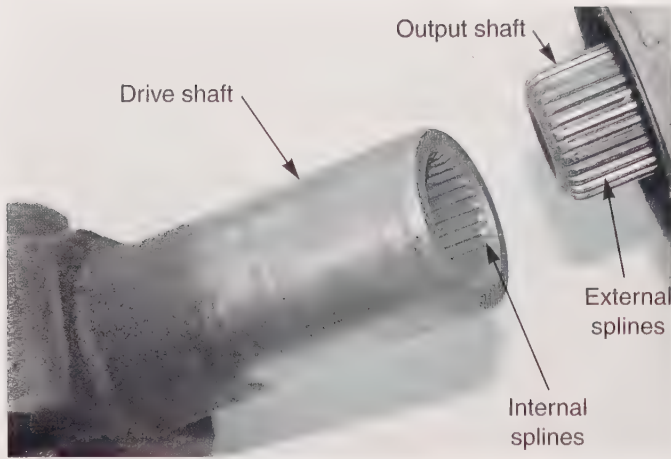


Figure 4-46. Note the internal and external splines on this drive shaft and output shaft.

while allowing power to be transferred through them. They are used on the sliding gears of manual transmissions and on slip yokes of drive shaft assemblies. They are used on clutch friction discs to drive manual transmission input shafts and on torque converter turbines to drive automatic transmission input shafts. They are used on other drive train parts as well.

Keys and Keyways

To keep a shaft and machine part, such as a gear or pulley, from rotating in relation to each other, keys and keyways are often used. Slots, or **keyways**, are cut in the two mating parts, and a **key** is inserted in the slots. Keys and keyways come in many variations. The most common for automotive use are the straight key and the Woodruff key, **Figure 4-47**. Sometimes, a single external spline is cut into a part and used as a key. A matching slot is cut into the mating part. The spline and slot are locked in place, and the two parts rotate as a unit.

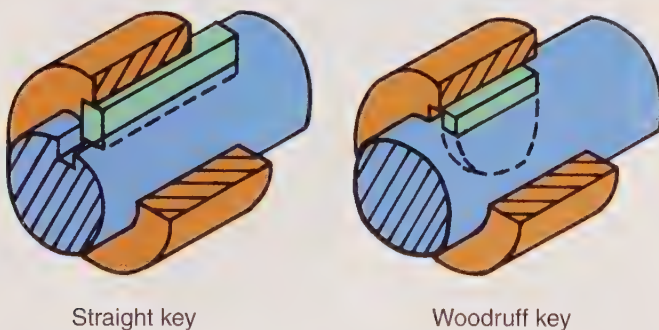


Figure 4-47. Keys are used to prevent rotation between a machine part and a shaft.

Summary

Vehicle drive trains are made up of many simple parts such as gears, chains, and bearings. Engine speed can be increased or decreased at the output of a gear or chain drive. A vehicle's direction can also be reversed by these parts. Friction can be reduced through the use of bearings.

Simple gears are toothed wheels that engage one another for the purpose of transmitting power. Speed and torque are increased or decreased through drive train gears. To improve fuel economy at higher vehicle speeds, overdrive gears are used.

Several classes of gears are used in vehicle drive trains. Spur gears are used to connect parallel shafts. The teeth on spur gears are straight and parallel with the shaft. Spur gears are sometimes used in manual transmissions. Spur gears are the simplest kind of gear. They can be noisy if the clearance is too large.

Helical gears have teeth that are cut at an angle. Helical gears operate more smoothly and quietly than spur gears. The angled cut of helical teeth puts a sideways thrust on the gears and shafts. This is often called end thrust.

Herringbone gears overcome some of the thrust and noise problems of helical and spur gears. Herringbone gears are sometimes called double-helical gears. These gears are seldom used in drive trains.

Bevel gears connect shafts that run at an angle. The angle of shafts used with drive train bevel gears is usually 90°. Similar to the bevel gear is the spiral bevel. Bevel gear teeth are straight, and spiral bevel gear teeth are curved.

Hypoid gears are similar to bevel gears, but the shaft centerlines do not intersect as they do with bevel gears. Otherwise, hypoid gears resemble spiral bevel gears.

Worm gears connect shafts that run at a 90° angle. Worm gears are useful when a large speed reduction is needed. They are seldom used on vehicle drive trains.

Rack-and-pinion gears consist of a flat bar with teeth cut into it (rack) and a small gear (pinion). Rack-and-pinion gears are usually used on the vehicle steering system.

A planetary gearset consists of a sun gear in the center, planet gears surrounding and meshed with the sun gear, and a ring gear meshed with the planet gears. The planet gears are attached to a planet carrier but are free to revolve within it. All planetary gearset gears are constantly in mesh with each other. To change gear ratios, different parts of the gearset are driven or held stationary. Planetary gearsets are used in overdrives and automatic transmissions.

Gear ratio is the speed relationship between gears. It can be summed up as the ratio between the number of teeth in any two meshing gears. A vehicle requires different gear ratios for different operating conditions. A vehicle must also have a reverse gear. Two or more gears can be arranged into a gear train that will provide an output shaft rotation opposite to engine rotation.

Given time, gears will wear out. Normal gear wear will occur after many miles. Low mileage gear failures are usually caused by abuse, overloading, or poor maintenance. Common tooth failure conditions are pitting, spalling, peening, scoring, and welding. Gear teeth may also overheat and lose their strength. Overheated gears wear out quickly.

Many gears are a slip fit with their shafts. Slip fit gears are held in position by other parts of the drive train or by snap rings. If the gear must turn with its shaft, it is held by a key or by splines. Sometimes the gear and shaft are machined from a single casting. Some gears are pressed onto the shaft they ride on. Removing these gears requires a gear puller or a hydraulic press.

Chain drives are often used where space is limited or to transmit power between a large distance. Every chain drive assembly consists of a chain and at least two sprockets. Some systems use more than two sprockets.

There are two major classes of drive chains. The roller chain consists of a series of pins, usually encased in rollers that are held in position by links. The pins or rollers engage the sprocket teeth. The silent chain consists of a series of leaves that are toothed to engage the sprocket teeth. The leaves are held in position by alignment pins.

Drive chain wear is compensated for by automatic tensioners that place a calibrated load on the chain. These tensioners are usually spring-loaded.

Drive chains can be checked for wear on or off the vehicle. A loose chain should always be replaced with a new one. If the sprockets show any tooth wear, they should be replaced. The chain and sprockets are usually replaced at the same time.

Bearings are used to reduce friction between moving and stationary parts. Bearings also guide and support rotating parts. The two major classes of bearings are friction and antifriction. Friction bearings are often pressed into a housing. They have no moving parts.

A rotating shaft slides around the surface of a friction bearing. Friction is reduced by a film of lubricant between the shaft and bearing. The lubricant may be supplied by pressure or splash. Some bearings are permanently lubricated by grease. Most friction bearings have slots to aid in oil distribution.

Friction bearings should always be checked for wear and proper size during any kind of service. Worn or damaged bearings should be replaced. In many cases, the shaft that rides on the bearing should also be replaced. Replacement bearings should be installed with a driver. Oil holes should be aligned with the matching holes in the housing before installation.

Antifriction bearings contain balls or rollers that rotate between races. The balls and rollers change sliding friction into rolling friction.

Ball bearings are used in clutches, transmissions, and transaxles. Roller bearings are used in transmissions and rear axles. Tapered roller, needle, and thrust bearings are all varieties of roller bearings.

Bearing loads usually change with shaft rotation, so that the bearing is alternately loaded and unloaded. This makes the use of high quality bearings critical.

The best way to remove an antifriction bearing is with a special puller or a hydraulic press. *Always* wear eye protection when removing a press-fit bearing. *Never* spin an antifriction bearing with compressed air.

Carefully clean and inspect antifriction bearings. A bearing with any kind of defect must be replaced. Always make sure you obtain the proper replacement bearing. New bearings should be left in their original wrappings until needed.

Antifriction bearings should be installed with the proper bearing driver. A hydraulic press is preferred. Never put driving pressure through the rolling elements, as this will damage the bearing and may cause injury. After installing the bearing, check that it rolls freely, with no binding.

Thrust washers are used to prevent excessive back-and-forth shaft movement. Retainer plates are devices used to hold gears and bearings in position. Collars are used to hold gears or bearings on shafts. Splines allow two rotating parts to move backward and forward in relation to each other while power is transferred through them. The internal splines on one component are designed to mate with external splines on another component. Keys and keyways keep two parts rotating with each other. The key is placed in two slots that are cut in the mating parts.

Review Questions—Chapter 4

Answer the following questions using the information provided in this chapter.

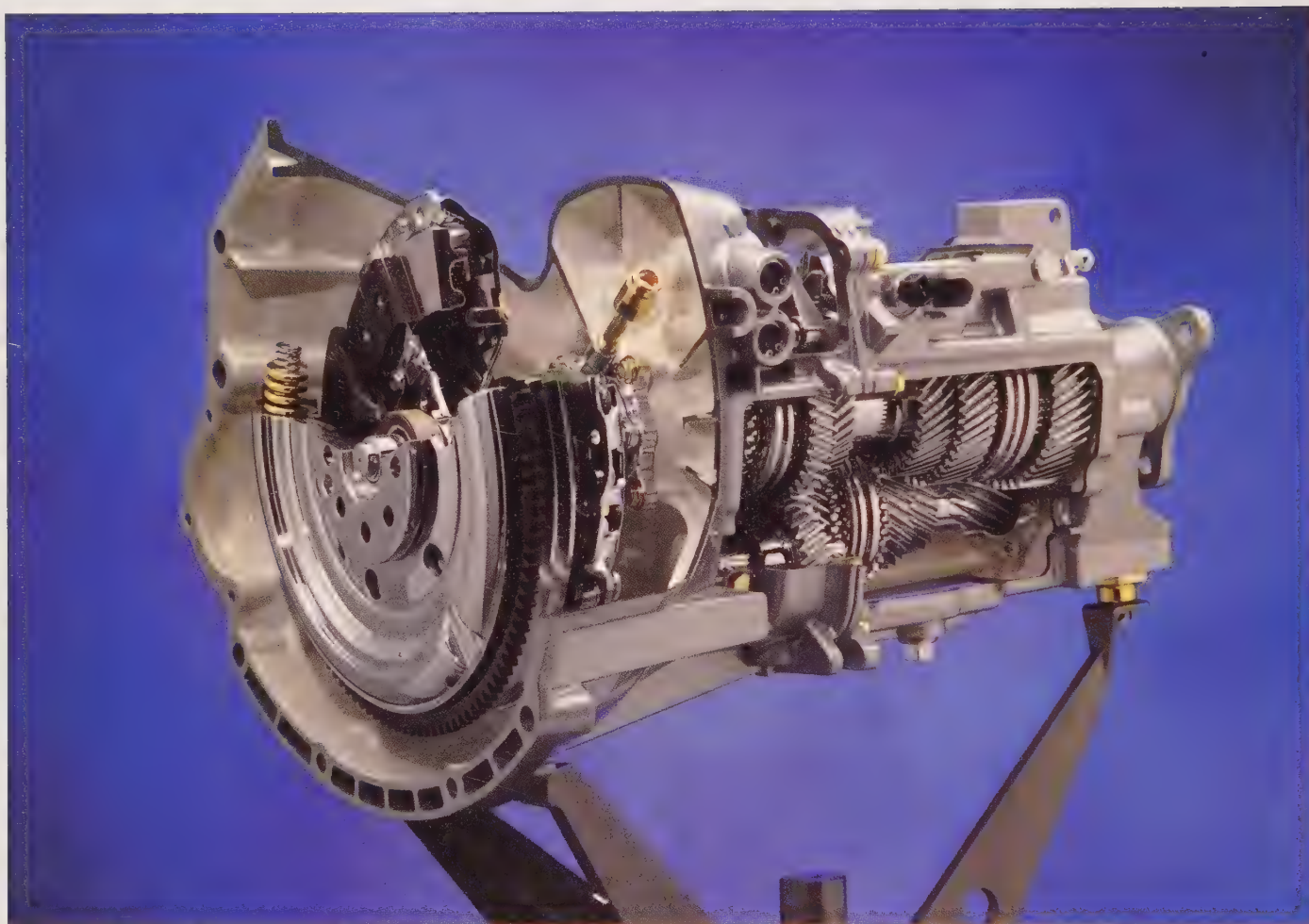
1. Engine power is transmitted by the action of ____.
2. Which of the following statements regarding gear manufacture is *not* true?
 - (A) Gear blanks are made from relatively hard steel.
 - (B) The faces of a gear are polished to a smooth finish.
 - (C) Gears are hardened in a heat-treating process.
 - (D) None of the above.
3. List and explain six types of gears.
4. Gear ____ is the amount of clearance or play between two meshing gears.
5. Describe what happens when gear teeth wear thin.
6. A failure condition of gears evidenced by flaking and chipping off of metal is known as ____.
7. A failure condition of gears evidenced by scratches on the tooth faces is known as ____.
8. ____ in gears may be caused by severe loads or by large foreign particles in the lubricant.
9. A ____ ____ transmits power in a straight line between two sprockets.

10. A(n)_____ can be used to take up slack in a loose chain of a chain drive.
11. A drive sprocket has 10 teeth, and the driven sprocket has 40 teeth. What is the drive ratio?
12. How do roller chains and silent chains differ?
13. What should you look for when inspecting a chain?
14. Sleeves, bushings, and insert bearings are all types of _____.
15. What is color change in a bearing a sign of?
6. Each of the following is part of a planetary gearset *except*:
 - (A) sun gears.
 - (B) spur gears.
 - (C) planet gears.
 - (D) ring gears.
7. Each of the following is a common gear problem *except*:
 - (A) pitting.
 - (B) scoring.
 - (C) splining.
 - (D) spalling.
8. Chain drives transmit power in a straight line between
 - (A) pulleys
 - (B) keyways
 - (C) CV joints
 - (D) sprockets

ASE-Type Questions—Chapter 4

1. Each of the following is a building block of the typical drive train *except*:
 - (A) gear drives.
 - (B) chain drives.
 - (C) bearings.
 - (D) belt drives.
2. Each of the following is achieved through the action of gears *except*:
 - (A) friction reduction.
 - (B) torque multiplication.
 - (C) power transmission.
 - (D) direction reversal.
3. Each of the following would result if bearings were not used in the drive train *except*:
 - (A) excessive friction between moving parts.
 - (B) wasted engine power.
 - (C) increased turning speeds.
 - (D) premature wearing of parts.
4. Technician A says that gears used in light-service applications can be made of plastic. Technician B says that gears used in light-service applications are generally made of high-strength steel. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
5. Each of the following gears is used to connect parallel shafts *except*:
 - (A) spur gears.
 - (B) bevel gears.
 - (C) herringbone gears.
 - (D) helical gears.
9. Technician A says that chain tensioners are designed to take up slack in chains. Technician B says that chain tensioners maintain pressure on the drive side of the chain. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
10. When finding chain drive ratio, Technician A says that the number of teeth on the driven sprocket should be added to the number of teeth on the drive sprocket. Technician B says that the number of teeth on the driven sprocket should be divided by the number of teeth on the drive sprocket. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
11. Technician A says that it is not necessary to replace sprockets when a chain is replaced. Technician B says that it is not necessary to replace a chain when its sprockets are replaced. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

12. Each of the following functions is served by bearings *except*:
- (A) reducing friction between parts.
 - (B) guiding and supporting rotating parts.
 - (C) preventing damage from misalignment.
 - (D) transmitting power.
13. The two major classes of bearings are _____.
- (A) friction and ring bearings
 - (B) radial and axial bearings
 - (C) friction and antifriction bearings
 - (D) roller and antifriction bearings
14. Each of the following is used as a coating for friction bearings *except*:
- (A) brass.
 - (B) copper.
 - (C) chrome.
 - (D) lead.
15. Technician A says that if the oil clearance is too tight, the oil cannot form an adequate surface between mating parts. Technician B says that a loose oil clearance will allow oil to leak out too quickly to maintain surface separation. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
16. To increase service life, all parts of an antifriction bearing are made of _____.
- (A) copper
 - (B) low-carbon steel
 - (C) high-strength steel
 - (D) babbitt metal
17. Each of the following is a roller bearing variation *except*:
- (A) needle bearings.
 - (B) thrust bearings.
 - (C) ball bearings.
 - (D) Torrington bearings.
18. Technician A says that it is acceptable to apply a light force through the rolling elements of an antifriction bearing. Technician B says that it is acceptable to spin the rolling elements of an antifriction bearing with compressed air. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
19. Technician A says that an antifriction bearing can be heated to facilitate installation. Technician B says that an antifriction bearing can be cooled to facilitate installation. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
20. Thrust washers are used _____.
- (A) to hold chain links
 - (B) around bevel gears
 - (C) to connect two sprockets
 - (D) between the end of a rotating shaft and its housing
21. Technician A says that thrust washers have grooves that allow oil to flow between the washers and the rotating parts. Technician B says that thrust washers are generally replaced when end clearance becomes too large. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
22. Each of the following is used to attach a retainer plate to a stationary housing *except*:
- (A) cotter pins.
 - (B) machine screws.
 - (C) bolts.
 - (D) snap rings.
23. Each of the following statements about collars is true *except*:
- (A) they are steel rings.
 - (B) they are a type of retainer.
 - (C) they should never be reused.
 - (D) they keep a shaft from rotating.
24. Technician A says that splines are used on sliding gears of manual transmissions. Technician B says that splines are used on clutch friction discs and on torque converter turbines. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
25. Which of the following is one of the most common keys for automotive use?
- (A) Spur key.
 - (B) Wood key.
 - (C) Woodruff key.
 - (D) Torrington key.



Note the many helical gears in this 5-speed manual transmission. Helical gears ensure smooth and quiet operation. (Ford)



Chapter 5

Sealing Materials, Fasteners, and Lubricants

After studying this chapter, you will be able to:

- ☐ Discuss the types of seals found in a drive train.
- ☐ Point out typical problems to look for when replacing seals.
- ☐ Explain proper methods of removing and installing seals.
- ☐ Discuss the importance of proper gasket installation.
- ☐ Describe how sealants are used in drive train repair.
- ☐ Summarize the different lubricants used in a drive train.

Technical Terms

Seal	Hardening sealer	Machine screw	Tensile strength
Nonpositive seals	Nonhardening sealer	Major diameter	Grade marking
Lip seal	Shellac	Minor diameter	Torque specification
Dust shield	RTV sealer	Bolt size	Tightening sequence
Ring seal	Anaerobic sealer	Nut size	Snap ring
O-ring	Thread-locking compound	Head size	Lubrication
Static seal	Thread sealer	Bolt length	Lubricant
Dynamic seal	Adhesive	Thread length	Additive
Seal ring	Epoxy	Thread pitch	Viscosity
Boot	Fastener	Coarse thread	SAE viscosity rating
Gasket	Threaded fastener	Fine thread	Lubricating oil
External gasket	Nonthreaded fastener	Metric thread	Gear oil
Internal gasket	Bolt	Thread-pitch gauge	Hypoid gear lube
Form-in-place gasket	Nut	Right-hand thread	Automatic transmission fluid (ATF)
Blown gasket	Cap screw	Left-hand thread	Grease
Sealer	Screw	Bolt grade	

Introduction

Drive train components must have adequate lubricant to operate properly. This means there must be protection against leaks, which could reduce lubricant supply. Components must also be protected from damaging dirt and moisture. This chapter describes the ways lubricants are retained in major drive train components and the ways dirt and moisture are kept out. In addition, this chapter identifies different types of fasteners and major classes of drive train lubricants.

This chapter will prepare you to perform some basic procedures required to successfully overhaul transmissions, transaxles, and other front and rear axle components. Later chapters will refer to descriptions and procedures covered here.

Seals

Seals are devices that keep fluids, such as lubricant, within a component or desired space. They also keep contaminants, such as air, dirt, and water, from getting into such places. Seals may be used for one or both of these purposes. In some applications, they are used to separate two different fluids. Seals are often used with rotating shafts or with shafts that slide back-and-forth axially. Seals are sometimes used to seal stationary parts. Some seals provide controlled leakage of fluid to allow some lubrication of moving parts. These are called **nonpositive seals**.

Types of Seals

Seals are found throughout the drive train. They are used in transmissions, transaxles, and rear axle assemblies. There are several different types of seals. The type used depends on the specific application. Seals commonly found in drive trains include lip seals, ring seals, seal rings, and boots.

Lip seals

Lip seals are used on rotating shafts in the drive train. A typical lip seal is shown in **Figure 5-1**. The casing is a rigid support for the other seal components. It is often made from stamped steel. The sealing element is designed to contact the rotating shaft. Most sealing elements are made from oil-resistant, synthetic rubber. The contact area is made in the form of a lip. A steel coil spring, often called a garter spring, or a garter, is wrapped around the sealing element. It places pressure on the sealing element to hold it tightly against the shaft. Some lip seals do not have a spring.

Figure 5-2 shows typical sealing action of a lip seal. Spring pressure plus internal pressure—fluid pressure in the seal cavity—cause the sealing element to be pressed tightly to the shaft. If there were not fluid pressure behind

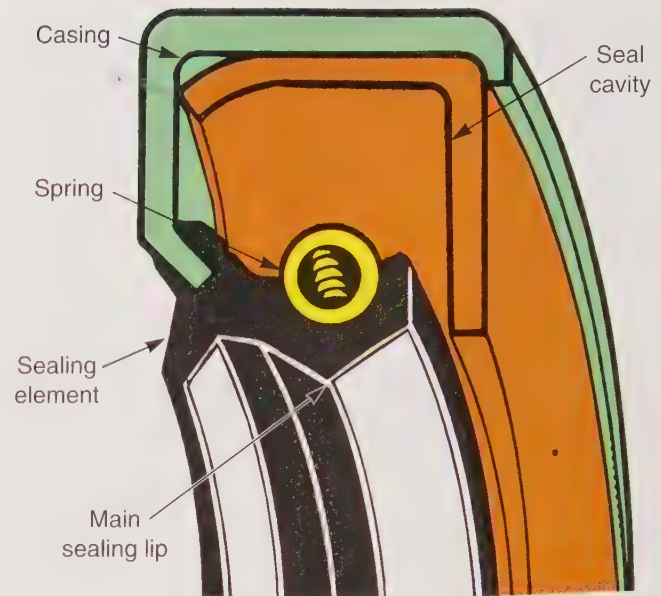


Figure 5-1. Components of a lip seal. The casing acts to hold the seal in position when installed. The lip seal is usually press fit into a stationary housing. The sealing element has the lip that contacts the shaft. The main sealing lip is placed nearer, or toward, fluid to be retained. An optional spring puts pressure on the sealing element to ensure contact with the shaft at all times. Note that the shape of the components may vary. (Ford)

the seal, the garter spring alone would still keep the sealing element in contact with the shaft.

A thin oil film (**Figure 5-2**) at the sealing lip reduces friction and provides additional sealing. If the seal is properly sized and installed, the oil film will not leak past the lip. Note that some lip seals have a felt wiper on the outside of the seal to catch small amounts of lubricant that get past the lip.

Different conditions require that different kinds of lip seals be used. Some of the variations are shown in **Figure 5-3**.

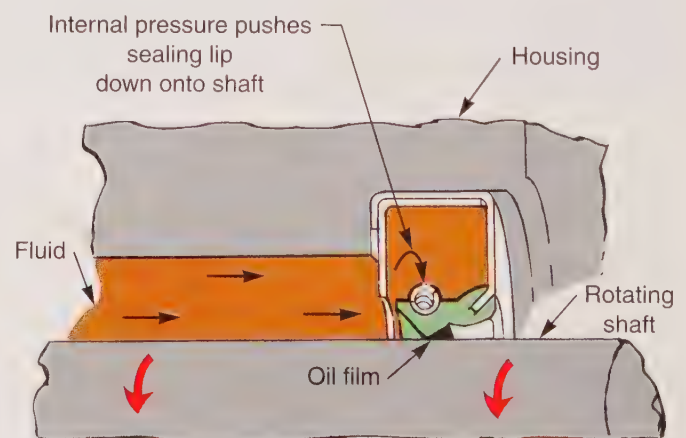
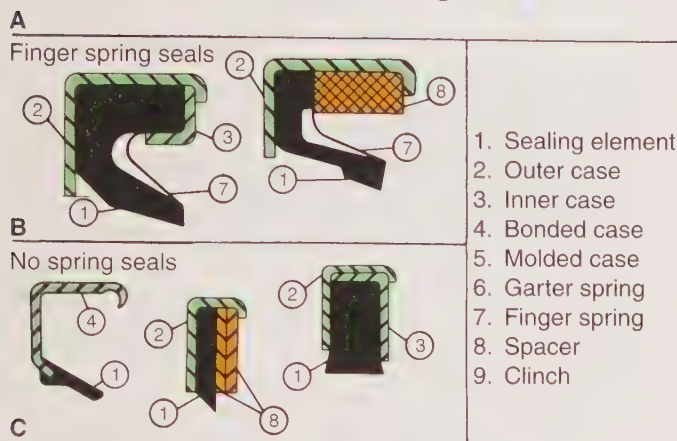
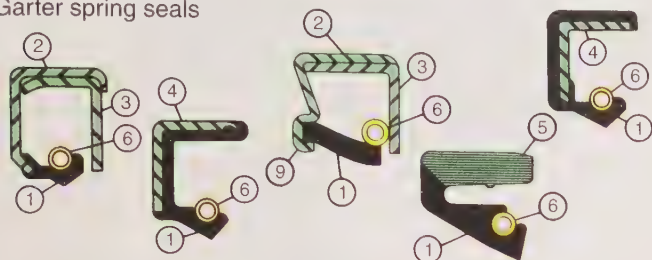


Figure 5-2. Note how a lip seal works. Pressure helps the spring hold the lip against the shaft. A film of oil between the lip and shaft helps to seal and reduce wear. Slight leakage at the lip is usually acceptable. (Caterpillar)

Components

SAE-ASTM Approved nomenclature

Garter spring seals



Multiple lip seals

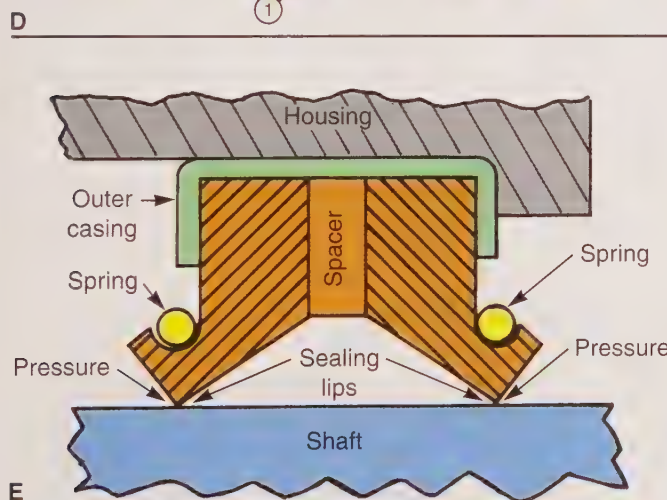
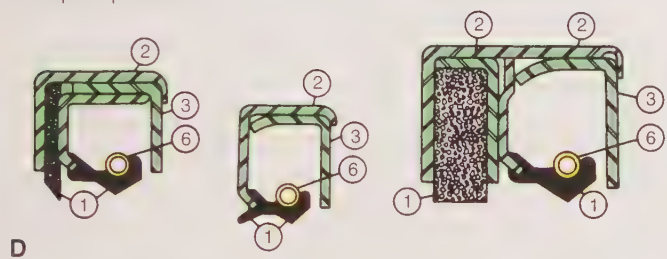


Figure 5-3. Study different kinds of lip seals used in drive trains. *A*—Design of sealing lip and garter spring depends on usage. *B*—This variation of lip seal employs a finger spring. *C*—Some lip seals require no springs. Fluid pressure may force sealing element against shaft. *D*—Some seals may have two or more lips. These seals are often used to seal exposed drive train parts. *E*—Lips point away from each other on this double lip seal. These seals are used where it is necessary to keep two fluids from mixing together. (Federal Mogul)

Figure 5-3A shows some of the ways the garter spring seal can be made. Notice the various lip constructions and placements of the garter. The design of the lip and garter spring depends on the seal's intended application. Variations in pressure, shaft endplay, and exposure to outside elements affect the design of the seal.

Figure 5-3B shows a variation of the lip seal. This type uses a finger spring, which is a cone-shaped series of fingers that place pressure on the sealing element. The function of the finger spring is similar to that of the garter spring; however, the action of the finger spring is such that it causes less pressure to be placed on the shaft and sealing element. This reduces seal and shaft wear, but some sacrifice is made in sealing ability. This type of seal is used in lower-pressure systems or for sealing components lubricated with grease.

Figure 5-3C illustrates lip seals that have no springs. These seals are used when the main requirement is to hold back contaminants. They may also be used in places where internal fluid pressure forces the sealing element against the shaft. These seals are not appropriate for applications where they would be subjected to external pressure. Most seals under external pressure require a spring to ensure a good seal.

Figure 5-3D shows seals that have more than one lip. These seals are used where external pressures are high or where seals are exposed to harsh conditions. The outer lip stops oil that has gotten past the inner lip, or main sealing lip, and it protects the inner lip from damage. Double lip seals are often used on drive train parts where there is exposure to the outside atmosphere. Examples include rear axle pinion oil seals and some transmission rear, or output shaft, seals.

A variation of the double lip seal has lips pointing away from each other, as shown in **Figure 5-3E**. These seals are used in some transaxles when it is necessary to keep transmission fluid and differential gear oil separated.

Some seals are protected by a **dust shield**, **Figure 5-4**. Dust shields are used in places where the seal would be exposed to large amounts of dirt and water. Examples are the front wheel bearing assemblies on front-wheel drive vehicles and the transmission and pinion oil seals of rear-wheel drive vehicles. A massive assault from dirt and water

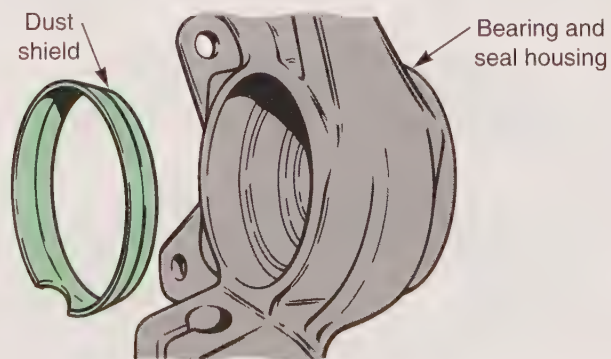


Figure 5-4. A dust shield keeps dirt and water away from sealing elements. This reduces seal failures in parts of the drive train exposed to excessive dirt and water. (Ford)

would overcome the seal, and the seal would quickly be destroyed, allowing lubricant to leak out. The dust shield acts as a deflector, or baffle, to keep most of the dirt and water away from the seal. The seal can then handle the small amount of material that does get through to it. Dust shields are very effective in helping to reduce the occurrence of seal failure.

Ring seals

A **ring seal** is a flexible ring that fits between two parts to keep fluid from leaking between them. Ring seals are used to seal stationary parts or circular parts that slide in their bores. A shallow groove is cut into one or both of the parts and closely fits the ring seal for the best seal. Ring seals can be round (O-ring), half-round (D-ring), or square (square-ring) in cross-section. See **Figure 5-5**. In drive trains, the round ring seal, or **O-ring**, is most common. Most O-rings have a small diameter through the cross-section as compared to the annulus, or ring. O-rings are used with both stationary and moving parts, while half-round ring seals (D-rings) and square ring seals (square-rings) are usually used with moving parts.

Stationary ring seals fit between nonmoving parts and are found in many parts of the drive train. They are often called **static seals**. Static seals form a perfect seal with no fluid leakage. **Dynamic seals** are sometimes used on shafts that enter through the transmission or transaxle case. These shafts are usually part of the shifter linkage. Dynamic seals flex slightly to allow for the back-and-forth motion and slight rotation of the transmission or transaxle input shaft as the gears are changed. Some dynamic seals allow slight fluid leakage. Slight leakage lubricates the seal and reduces wear. See **Figure 5-6**, which compares the static and dynamic seal. Dynamic seals are not used to seal parts that rotate constantly.

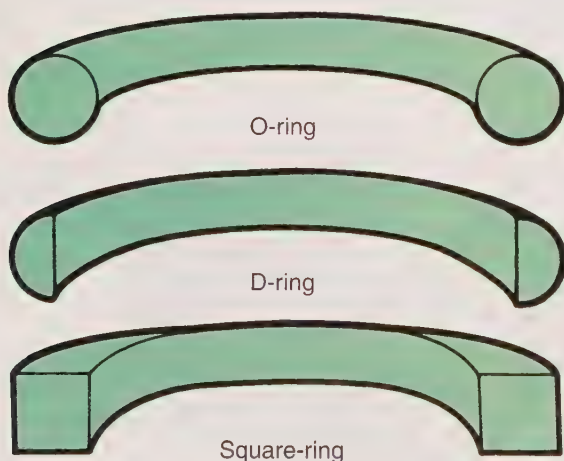


Figure 5-5. Types of ring seals. O-rings and D-rings are almost always made of synthetic rubber. Square-rings may be made of rubber, metal, or Teflon. These rings are all designed for specific applications. (Ford)

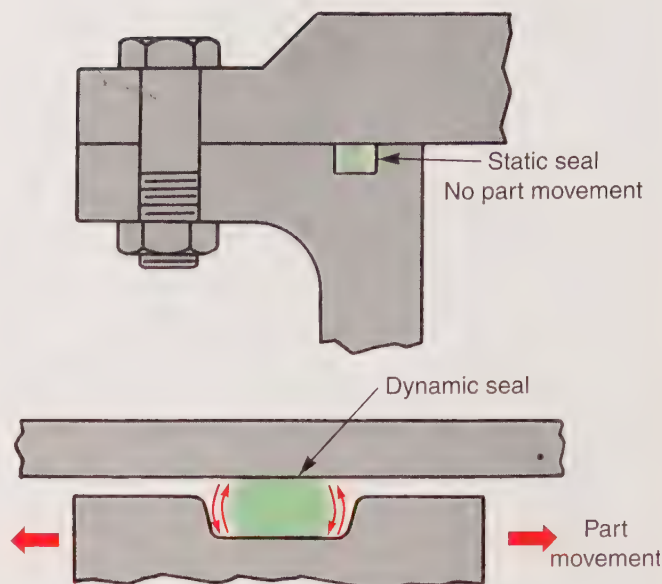


Figure 5-6. Static and dynamic seals. Static seals are used to seal parts that will not move in relation to each other. Dynamic seals seal where there is relative motion between two parts. (Deere & Co.)

Seal rings

Seal rings (not to be confused with ring seals) are metal or Teflon® rings. They seal oil pressure directed to or through passageways in rotating shafts or drums. Seal rings are nonpositive seals. They are designed to allow slight leakage for lubrication of moving parts. The rings are installed in grooves machined in the shaft. Seal rings are sometimes used on rotating shafts in manual transaxles and transfer cases, especially those with internal oil pumps.

Metal seal rings resemble small piston rings. Some metal rings are locking types, with small latch tabs to hold the ring together. Other metal rings are the straight, or butt, type. This type depends on the size of the surrounding bore for a tight fit. See **Figure 5-7**.

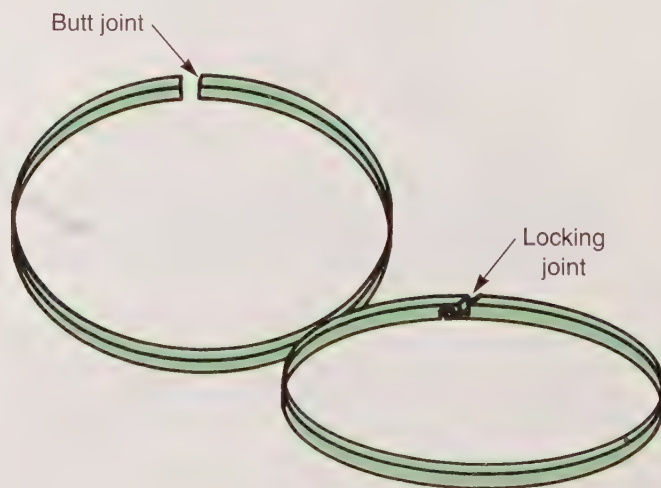


Figure 5-7. Seal rings with locking and butt joints are shown here. Be careful how you handle these, as they are very brittle.

Teflon seal rings are one-piece rings made of Teflon and plastic. Teflon seals resemble square-cut ring seals (square-rings) and are usually made in bright colors. They are often used in original installations because they allow lower-cost assembly.

Both types of seal rings seal in hydraulic fluid to maintain pressure. They do this by forming a mechanical seal between the moving parts. The outside diameter of the ring seats against the inner surface, or bore, of a rotating part. The side of the ring, moved by pressure, seats against one side of the shaft groove. This prevents practically all fluid leakage. See **Figure 5-8**.

The seal ring should rotate with the bore. If not, the bore surface will wear, allowing pressure loss. (The side of the ring will rotate against the shaft groove, and the groove will incur slight wear.)

Metal seal rings can be removed without being damaged; although, most manufacturers recommend replacing the rings when a transmission is overhauled. Teflon seal rings cannot be removed without being destroyed. In many cases, the original Teflon rings can be replaced with metal rings.

Boots

A **boot** is a pleated, or accordion-like, flexible cover made of synthetic rubber or plastic. It is used to retain lubricant and keep out contaminants while allowing part movement. For example, a boot is used to enclose constant-velocity joints (CV joints) used on front-wheel drive vehicles. Straps or clamps—one end around the drive axle, and one end around the CV joint yoke or outer race—fasten the ends of the boot. The boot allows angular movement while keeping out dirt and retaining grease. Look at **Figure 5-9**.

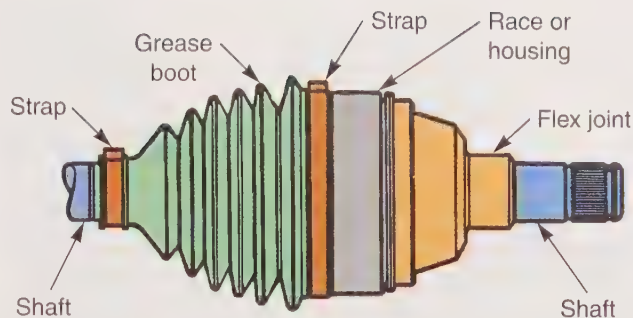


Figure 5-9. Boots are designed to retain grease and keep dust out of parts such as constant-velocity joints. Boots such as these are usually found on front-wheel drive vehicles. (General Motors)

causes messy, slippery floors and may damage other vehicle components. A seal that leaks in (allows contaminants to reach lubricant) allows lubricant to become contaminated, which may result in damage to components.

Seal leaks

Almost all seal problems show up first as leaks. Seal leaks can be caused by several problems. The most common problem is a worn or damaged seal. It is not unusual for a seal in an older vehicle or a vehicle with high mileage to leak. This is usually caused by wear and hardening of the sealing element. Sometimes, the leak occurs because a lip seal garter spring becomes weak. **Figure 5-10** points out the areas of a lip seal that commonly wear. Ring seals usually become hard and shrink. When this happens, they no longer conform to the grooves they are sealing. A new ring seal generally solves the problem.

Sometimes, the shaft or housing for the seal wears out, causing a leak. When replacing a lip seal having many miles of service, always check the shaft for signs of wear. The shaft tends to wear where the sealing lip contacts it. See **Figure 5-11**. If this area is not worn, the standard replacement seal works well. Many times, however, the shaft is so worn that the standard replacement does not correct the problem. In most of these instances, the shaft must be replaced.

Seal Service

A leaking seal should be replaced when it is discovered. When a seal leaks out (allows lubricant to leak from a desired area), a component eventually runs out of lubricant and is damaged. The leaking lubricant often

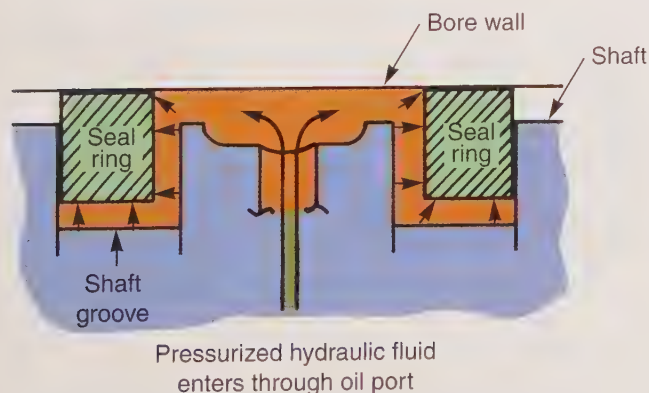


Figure 5-8. This is a partial view of a shaft in a bore. Seal rings are installed in the shaft grooves. Pressurized hydraulic fluid keeps seal rings tight against the side of their grooves.

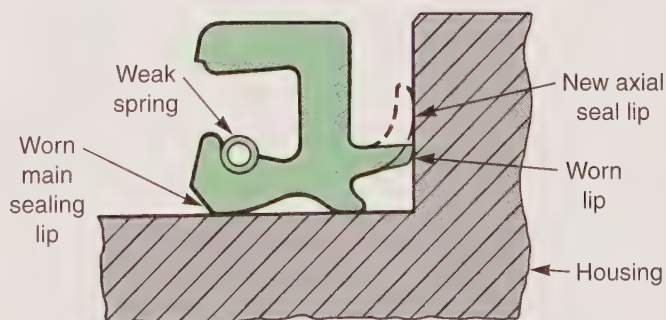


Figure 5-10. Depicted are conditions of wear and damage that can affect performance of a lip seal. Any one of these problems can cause a leak. (Ford)

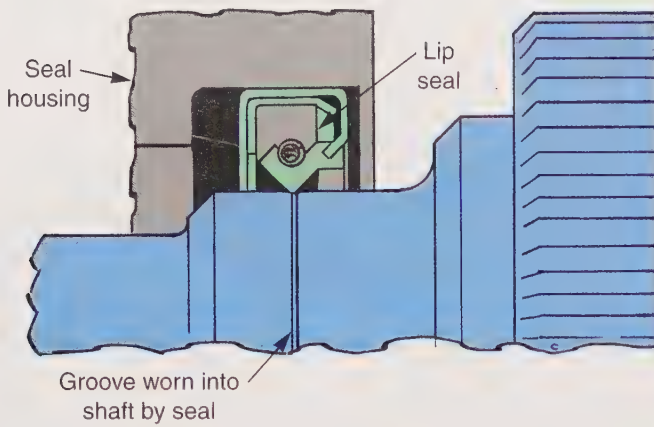


Figure 5-11. A groove worn in a shaft can cause a leak. A new seal alone may not solve this problem. In many instances, you will find that the shaft must be replaced or a sleeve must be installed. (Caterpillar)

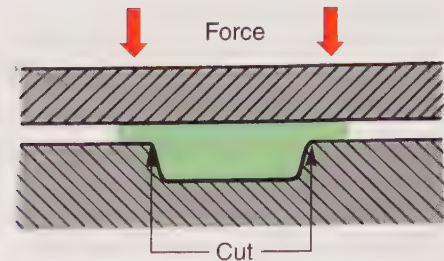
In some cases, the problem can be corrected by using a replacement seal that contacts the shaft to either side of the contact area of the original seal. Sometimes, on more expensive parts, pressing a sleeve over the worn shaft area can repair the shaft. A seal is then fitted to the sleeve. The sleeve adds to the diameter of the shaft, so a larger lip diameter will be required to fit the sleeve.

When checking a shaft for signs of wear, check for excessive play in the shaft. If there is too much lateral, or side-to-side, movement, the seal cannot form a good sealing surface. The shaft or shaft bearings should be replaced. If a seal seems to have failed at low service mileage, check for shaft or housing problems. Also, check for excessive dirt or metal particles, which will cause rapid seal wear.

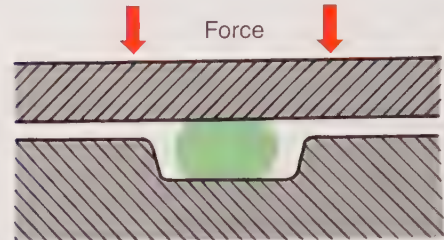
One of the most common causes of seal leakage following a repair is the installation of the wrong seal. The wrong size lip seal will leak almost immediately. An improperly sized ring seal may seal for a few minutes or hours, but it will eventually leak. A seal that is not the right size should *never* be used. See **Figure 5-12**.

Another most common cause of seal leakage after a repair job is improper installation, evidenced by a cocked or distorted seal. See **Figure 5-13**. O-rings that are improperly installed will leak immediately. A lip seal that is not perfectly aligned with the shaft will not make good contact with the shaft. The seal will begin leaking, wear unevenly, and possibly damage the shaft.

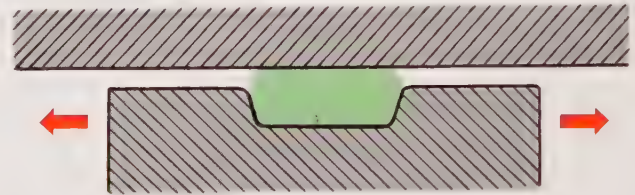
Shaft or housing damage attributed to other causes can damage a seal and cause it to leak. Examples of bore and shaft damage are shown in **Figure 5-14**. Scratches and dents from hammering out an old seal, grooves, sharp keyway edges, corrosion, and improper machining can cause seal leakage. A loose or bent shaft will cause seal distortion and leaks, even with a new seal. All of these problems should be looked for and eliminated before installing a new seal.



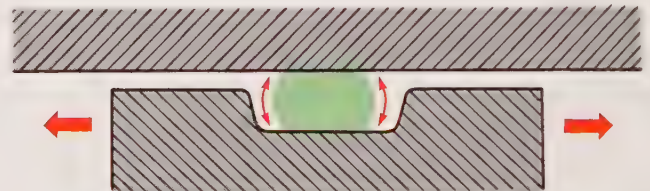
Incorrect: Too-large ring



Correct: Slight squeeze
O-ring in Static Use



Incorrect: No rolling action



Correct: Rolling action
O-ring in Dynamic Use

Figure 5-12. Proper sizing of the O-ring is important. Note what happens when proper and improper sizes of static and dynamic seals are used. (Deere & Co.)

Seal removal

The following precautions should be observed during any seal removal operation:

- ☐ Always wear eye protection when using a seal puller or driving the seal from its housing.
- ☐ Do *not* damage the seal bore or the shaft.
- ☐ Check all related parts for damage that could result in a seal leak.

Seals should be removed carefully. Most static O-ring seals are compressed between two stationary drive train

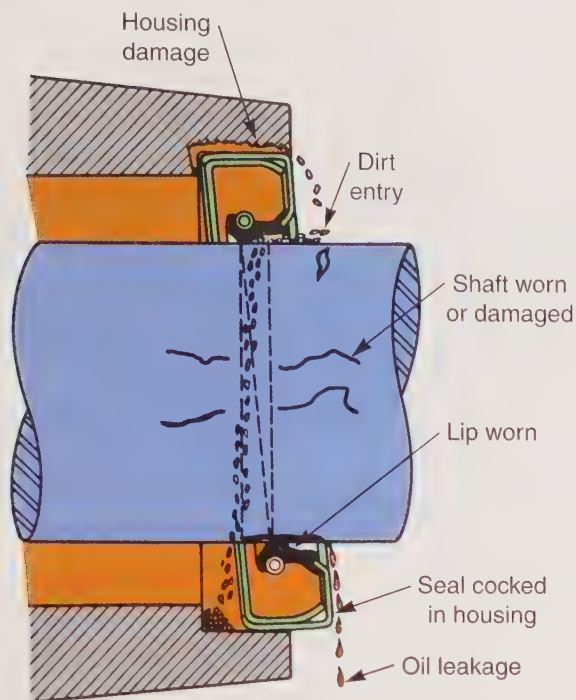


Figure 5-13. A cocked lip seal can cause many problems. The most obvious problem is leaking, but a cocked seal can also cause shaft and housing damage. The housing will usually be damaged when the seal is installed. The shaft will wear because of the uneven pressure placed on it by the lip. (Deere & Co.)

parts. Some O-rings are held by a retainer plate. After the plate or component has been disassembled, the O-ring can be lifted or pried out of its groove. Dynamic O-rings are removed by removing the piston from its cylinder to expose the O-ring. The O-ring is then carefully pried from its groove.

Most lip seals are pressed into a bore that is part of a drive train component. A seal pry tool, such as that shown in **Figure 5-15**, should be used to pry out the old seal. Alternate

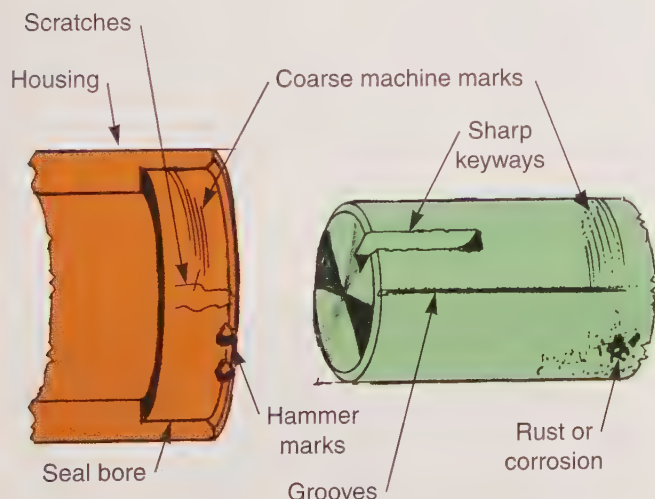


Figure 5-14. Defects in the shaft and housing can ruin a seal during installation. Sharp edges on shafts can cut the seal as it is slipped into place. Housing defects can damage the seal casing. (Caterpillar)

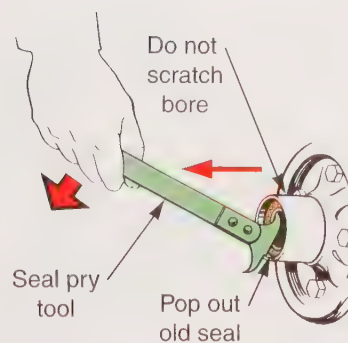


Figure 5-15. The best way to remove a seal is with a seal puller. If a puller is not available, seals can be removed by several other methods. Always be careful not to damage the seal housing during removal. (Lisle)

pressure on the seal from side to side. This will help the seal come out easily, with minimal damage to the bore.

Another way to remove the seal is to use a slide hammer with a jaw puller. The jaw is pushed through the seal and then expanded. Or, instead of using a jaw puller, drill two small holes directly across from each other in the seal's metal casing. Thread a screw attached to a slide hammer into one of the holes. Using the slide hammer, carefully pull the seal from the bore. To remove the seal evenly and prevent it from becoming wedged, alternate the slide hammer from one hole to the other during the removal process.

If you can reach the seal from behind, you can drive it out of its bore with a seal driver or a hammer and a soft metal drift. Be careful not to damage the housing.

Once the old seal has been removed, check the housing, shaft, and all other related parts. If leakage was a problem, these parts may provide clues as to the cause. Correct any problems before installing a new seal.

If a standard replacement seal is to be used, check its part number against the old seal's part number to ensure they match. If they do not, you could have the wrong replacement seal or it could be that a new number has since been assigned to the particular seal. Otherwise, it is possible that the old seal was the wrong one. If there was a problem with the original seal, this could well have been the cause.

Seal installation

Two general points should be made in regard to seal installation prior to discussing specifics. First, a seal should not be removed from its wrappings until ready to be installed. This will help keep the replacement seal clean. Also, the seal contact surfaces should be coated with lubricant prior to assembly, **Figure 5-16**. For this, you should use the same kind of lubricant used in the part or assembly.

If a ring seal is to be installed, lubricate the groove. Carefully install the ring seal in the groove. Make sure static O-rings fit properly in the groove before reassembling the component. For dynamic O-rings, check for proper size around the piston and the bore.

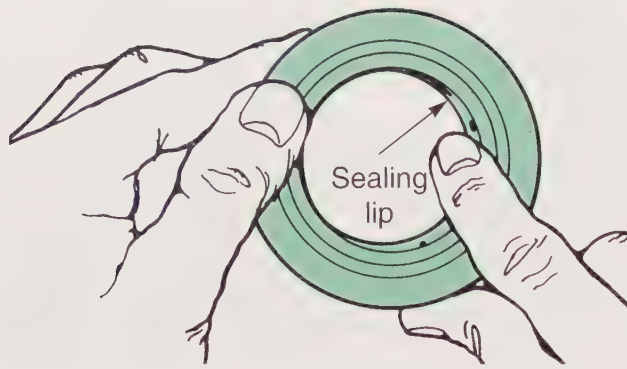


Figure 5-16. Always lubricate the sealing lip of a new seal before installation. Prelubrication makes the seal easier to install and provides an oil film at the lip during break-in. (Ford)

If installing a lip seal, lubricate the shaft, as well as the sealing lip. Again, use the correct lubricant. If the seal has a metal casing and it is not precoated by the manufacturer, coat the casing lightly with a nonhardening sealer, **Figure 5-17**.

If the lip seal will be installed into a housing bore with the shaft already installed, make sure the shaft is free from burrs or scratches that could damage the seal. If necessary, polish the shaft with crocus cloth, which is an abrasive cloth that has very fine particles of iron oxide. In addition, to protect a seal from drilled holes, splines, keyways, square shaft ends, and other sharp spots, a temporary collar may be formed over the spot with a piece of smooth, heavy paper or a plastic sleeve.

Making sure the seal is oriented in the proper direction, slide the seal over the shaft until it reaches the housing. Drive the seal in with a seal driver that closely matches the outside diameter of the seal. Drive it in squarely until it is properly seated. After installation, make sure the garter spring (if used) did not come loose and there was no damage from the driving action. **Figure 5-18** shows a seal driver being used to install a seal in a bore.

In an emergency, a large socket or pipe that closely matches the outside diameter of the seal can be used as a driver. It is also possible to install a seal with a hammer if

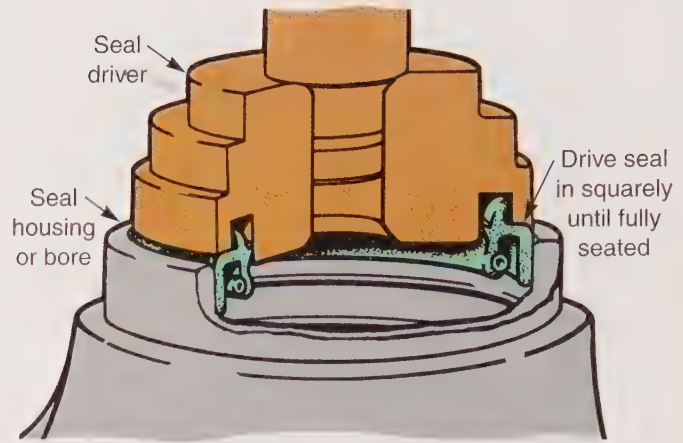


Figure 5-18. An improperly installed seal will be ruined immediately. Watch the seal carefully as it is being installed to ensure that it goes in squarely with the bore. (Ford)

done carefully. The seal should be lightly tapped into the bore. Alternate hammer taps from side to side until the seal is seated. Failing to do it this way will cause the seal to become cocked and bent.

Gaskets

Gaskets are a kind of static seal used on nonmoving parts. Gaskets are used in output shaft housings, bearing covers, shifter covers, and differential housing covers. Gaskets are never used to seal moving parts.

Gaskets are used to prevent the leakage of lubricant between two parts that are bolted together. There are external and internal gaskets. **External gaskets** keep fluid from leaking out of a component. They also keep out dirt or moisture. **Internal gaskets** prevent crossover of fluids within a component. In a few limited-slip differentials, gaskets may be used internally to prevent loss of oil pressure.

Gaskets used on drive trains are normally cut from a single piece of gasket material. Gasket material is flexible. This allows gaskets to seal by conforming to imperfections in mating surfaces. See **Figure 5-19**. When the parts are tightened, the gasket compresses and deforms, filling in the low spots, scratches, and other imperfections in the mating surfaces. This results in a leakproof seal.

Gasket Materials

Most gaskets used in drive trains are made of oil-resistant paper. These are sometimes called chloroprene gaskets. This material is often mixed with a substance such as rubber to add flexibility and strength.

Where mating parts will be subjected to expansion and contraction, gaskets made from a synthetic rubber called neoprene are often used. Natural rubber cannot be used because petroleum-based lubricants, such as gear oil and transmission fluid, will make it swell and fail in service.

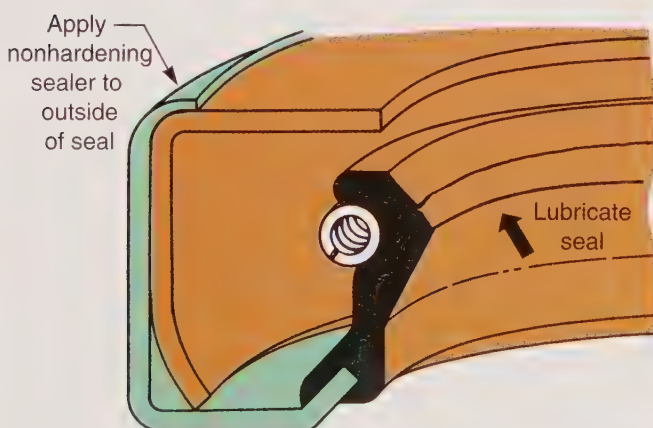


Figure 5-17. If the lip seal has a metal casing, apply nonhardening sealer to the casing before installation. This step is not necessary if the casing has a flexible coating. (Deere & Co.)

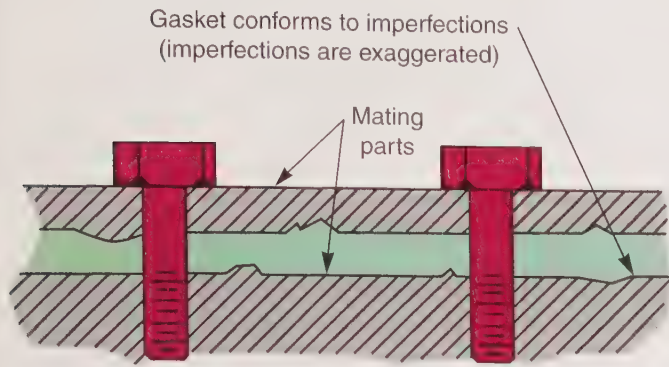


Figure 5-19. Gaskets are made of relatively soft materials. This flexibility enables the gasket to conform to imperfections in the gasket mating surfaces. Please note that the imperfections and gasket conformity are exaggerated in this figure.

Some gaskets are made of copper or aluminum. These gaskets have a ridge running around their perimeter. When mating parts are tightened down, the ridge is compressed, providing the seal.

Thick gaskets of cork or felt are usually used to provide seals for assembly covers made of sheet metal. The thickness of the gasket helps to compensate for distortion of the sheet metal cover, **Figure 5-20**. These thick gaskets are often coated with Teflon to reduce sticking when the gasket is removed.

Some gaskets are made from a sealer. These are called **form-in-place gaskets**. The sealer normally comes in a tube. It is applied directly to one of the mating part surfaces. The parts are assembled while the sealer is still wet to the touch. More will be said about form-in-place gaskets later on in this chapter.

Gasket Problems

Gaskets are sometimes a source of problems. Often, they are blamed for problems really caused by other components. If a gasket appears to be leaking, make sure the leak is not coming from a cracked part or a nearby component.

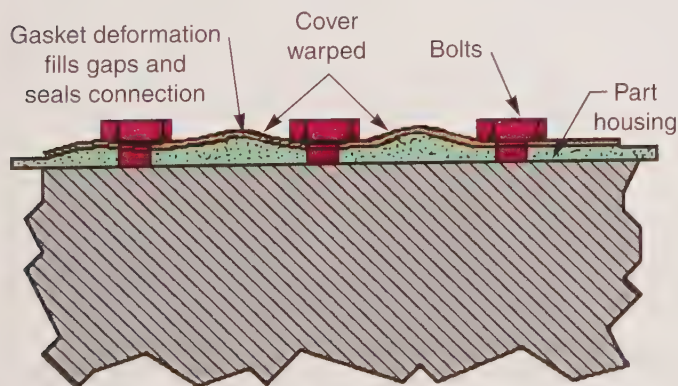


Figure 5-20. Thick gaskets can sometimes compensate for warped sheet metal cover plates or pans.

Some gasket leaks are caused by loose bolts. Tightening the bolts properly may stop the leak. Sometimes, however, pressure from within tears out a piece of gasket. This is called a **blown gasket**. Blown gaskets are usually caused by loose fasteners or warped mating parts that do not tightly hold the gasket. Also, overtightening attaching bolts can crush the gasket, resulting in a weak spot that will blow out much more easily.

Gasket Service

Gasket service involves disassembling parts, removing the old gasket, cleaning mating surfaces, and installing a new gasket. Some basic rules for removing and replacing gaskets are:

- ❑ Verify the cause of the problem before disassembly. Often, what appears to be a gasket problem is a defective part or an improper part installation.
- ❑ Avoid causing part damage during disassembly or gasket removal. Although the gasket material is designed to compensate for scratches, dents, and nicks, always work carefully. Aluminum parts are especially easy to damage.
- ❑ Thoroughly clean the gasket surfaces. If the old gasket must be scraped off, use a dull scraper on the mating surfaces to avoid damaging them.
- ❑ Thoroughly wash the parts with solvent and blow-dry with air pressure. *Avoid* using rags to dry internal drive train parts. Rag lint could damage bearings.
- ❑ Check the new gasket shape. It should conform to the mating part surfaces and the old gasket. Make sure the gasket contains all of the required holes and all gasket holes match the holes in the mating parts.
- ❑ Use sealer *only* if needed. (Sealers are covered in a following section.) If the manufacturer recommends using sealer, place a thin coat on the gasket.
- ❑ Hand-tighten all bolts before using a wrench. Make sure all bolts start in their respective holes.
- ❑ Tighten the bolts in proper sequence. If a tightening sequence is not given, start from the middle and work toward the edges. Alternate the tightening in a criss-cross pattern.
- ❑ Tighten all bolts in small steps. After the final tightening sequence, recheck all of the bolts.
- ❑ Do *not* overtighten the bolts. This is especially important when installing pans or other sheet metal parts.

Making a gasket

Sometimes, a replacement gasket is not available, and you must make a gasket from a sheet of gasket material. Simple gaskets can be made easily by either of two methods.

One method is to lay a sheet of gasket material on the component that requires a gasket or lay the component over the gasket material. Use a pencil to trace the outline of the sealing surface on the gasket material. Use scissors to cut the gasket material to the desired pattern.

The other method is to lay the sheet of gasket material over the component and use a brass or ball peen hammer to lightly tap the gasket against the sharp edges of the sealing surface. Tap out one or two bolt holes first. Then, thread bolts into the holes to hold the gasket material. Go back to tapping around the sealing surface until you obtain the proper gasket shape. Trim any rough edges with scissors.

Sealers

Sealers, or **sealants**, are used for various reasons. They can improve the sealing ability of a gasket. They can take the place of a gasket. They can be used to hold a gasket in place during reassembly. Sometimes, sealers are used to improve the sealing ability of dynamic seals and hose connections.

Types of Sealers

There are several types of sealers. They have different properties and are designed for different purposes. Always read the manufacturer's label and a service manual before selecting a sealer. Study the use and characteristics of sealer types shown in **Figure 5-21**.

Hardening sealers

Hardening sealers are used on parts that remain assembled for long periods of time, possibly the life of the vehicle. For example, they are used on some threaded fittings and fasteners. Sometimes, they are used for filling uneven sealing surfaces. Hardening sealers are usually resistant to heat and chemicals.

Nonhardening sealers and shellac

Nonhardening sealers are used on parts that will be taken apart occasionally, such as differential covers. Hardening sealers are also used on some threaded fasteners and fittings and on hose connections. They are resistant to most chemicals and to moderate heat.

Shellac is a gummy, sticky substance that remains pliable. It is frequently used on gaskets of fibrous materials for sealing and for holding gaskets in place during assembly. Shellac could be classified as a nonhardening sealer.

Form-in-Place Gaskets

Form-in-place gaskets are sometimes used instead of conventional gaskets. They are applied in fluid form directly to parts to be sealed. The gasket is formed when the parts are tightened together and the substance cures (dries, or sets up). Form-in-place gaskets are commonly made of either RTV sealer or anaerobic sealer.

RTV sealer

RTV (room temperature vulcanizing) sealer is a silicone sealer. It cures to a rubber-like consistency to form the gasket. RTV sealer is usually used on thin, flexible flanges.

RTV sealer normally comes in collapsible tubes. The substance is usable for some time after a tube is opened. After the expiration date, the sealer may not cure; in which case, it would not make a good seal. Always check the expiration date on the package before using the sealer. Use a new tube if in doubt.

To apply RTV sealer, **Figure 5-22**, lay about a 1/8" (3 mm) continuous bead around the edge of the part. Keep the

Type	Temperature range	Use	Resistant to	Characteristics
shellac	-65° to 350°F (-54° to 177°C)	general assembly: gaskets of paper, felt, cardboard, rubber, and metal	gasoline, kerosene, grease, water, oil, and antifreeze mixtures	dries slowly sets pliable alcohol soluble
hardening sealer	-65° to 400°F (-54° to 205°C)	permanent assemblies: fittings, threaded connections, and for filling uneven surfaces	water, kerosene steam, oil, grease, gasoline, alkali, salt solutions, mild acids, and antifreeze mixture	dries quickly sets hard alcohol soluble
nonhardening sealer	-65° to 400°F (-54° to 205°C)	semipermanent assemblies: cover plates, flanges, threaded assemblies, hose connections, and metal-to-metal assemblies	water, kerosene, steam, oil, grease, gasoline, alkali, salt solutions, mild acids, and antifreeze solutions	dries slowly nonhardening alcohol soluble

Figure 5-21. This table shows some types of sealers and their uses. No one sealer can be used for every sealing job. (Fel-Pro)

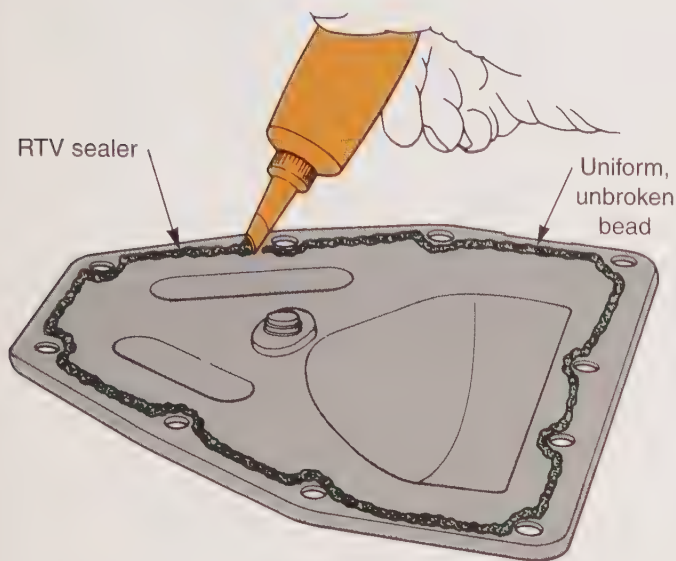


Figure 5-22. RTV sealer can be used to make gaskets on many parts. (Chrysler)

bead to the inside of the mounting holes—preferably, encircle them. Do not permit any breaks in the bead or a leak will result. Components should be assembled and tightened while RTV sealer is still wet to the touch. You should have about 10 minutes to get the parts assembled before the sealer dries. Should it be necessary, RTV sealer may be removed with a rag before it cures.

Anaerobic sealer

Anaerobic sealer cures to a plastic-like substance in the absence of air. It remains fluid as long as it is exposed to the atmosphere. Anaerobic sealer is used with tightly fitting, thick parts, which air cannot penetrate. It is used between two smooth, true surfaces, not on thin, flexible flanges, which may be penetrated by air. Anaerobic sealers will not harden in their containers because the air space in the containers provides enough air to prevent hardening.

Anaerobic sealer should be applied sparingly. Lay about a 1/16" (2 mm) diameter bead on one surface only. It is recommended that the sealer encircle each mounting hole. The parts should be assembled and tightened within 15 minutes of applying the sealer.

Before any kind of sealer is applied, there are a few preliminary steps that must be taken. All loose material and lubricant must be removed from the part mating surfaces. To do this, scrape or wire brush the part surfaces at these locations. Check that the part surfaces are reasonably flat where the material is to be applied. Use a shop rag and solvent to wipe off any oil and grease on the surfaces. The sealing surfaces must be clean and dry before applying sealer. Finally, before applying any sealer, always refer to the manufacturer's instructions to be sure you use the right kind.

Thread-Locking Compounds and Thread Sealers

Thread-locking compounds are used to prevent threaded fasteners, such as bolts, screws, and nuts, from loosening. These compounds are a type of anaerobic sealer. When they are applied to a threaded fastener and the fastener is tightened, the lack of air causes them to harden. Thread-locking compounds make the removal of a fastener very difficult. They should be used only when the vehicle manufacturer recommends them.

Before applying thread-locking compound, threads should be cleaned and sprayed with a primer. This will reduce the setting time of the compound. Apply the compound as shown in **Figure 5-23**. Then, install the fastener.

It requires considerable turning effort to loosen a fastener that was installed with thread-locking compound. Once the "lock" is freed, a fastener installed with thread-locking compound also will be more difficult to remove. This is because the thread-locking compound remains in the threads, which tends to jam the fastener. If a fastener will not loosen, low heat may soften the compound and allow the "lock" to be freed.

Thread sealers are used to seal any threaded fasteners that extend into the oil-lubricated interior of a drive train component. Oil will seep out through the threads if a sealer is not used. Thread sealers should be applied to the fastener threads only after the threads have been thoroughly cleaned.

Adhesives

Adhesives are used for holding parts together. They are *not* used as sealants. Adhesives are sometimes used to hold gaskets in place or small parts together during assembly. Before applying adhesives, make sure the surfaces to be bonded are clean. Some adhesives are applied in a two-step process; a setting agent is applied first, and then the

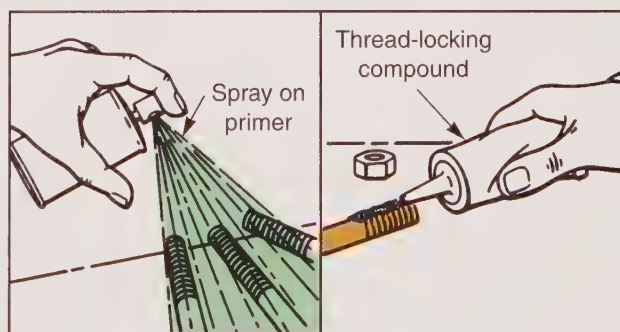


Figure 5-23. Thread-locking compounds are used when a threaded fastener must not loosen. Thread-locking compounds remain liquid in the container and can be easily applied to the threads of the fastener. They harden and form a solid bond when the fastener is tightened. (Deere & Co.)

adhesive is applied. Other adhesives are two-part mixtures applied in a one-step process. These are sometimes called **epoxies**. Epoxies are mixed just before application.

Fasteners

Fasteners are devices used to hold, or fasten, parts together. Fasteners can be divided into threaded and non-threaded varieties. Nuts, bolts, and screws are all types of **threaded fasteners**. Snap rings are a type of **nonthreaded fastener**.

Threaded Fasteners

The most common kinds of threaded fasteners used on drive trains are nuts and bolts. A **bolt** is a threaded rod with a head on one end. The head is usually six-sided (hex head), although some special bolts have square or round heads. A **nut** has inside threads and, commonly, a six-sided outer shape.

Bolts can be threaded into nuts or parts with threaded holes. A bolt that threads into a part instead of a nut is called a **cap screw**. The threads of the bolt and nut or threaded part provide a holding force to keep parts assembled.

Screws resemble bolts but are generally smaller. Screws are designed to thread directly into a nut or threaded hole. Screw heads are generally designed to accept screwdrivers. **Machine screws** are common on drive trains. They are usually smaller than cap screws and are flat across the bottom.

Threaded Fastener Classification

Threaded fasteners are used throughout the vehicle and are often used to assemble drive train parts. Threaded fasteners are often referred to by such terms as bolts, nuts, and screws. Any fastening device that uses threads to tighten and hold is a threaded fastener. Threaded fasteners are made in many different sizes, strengths, and thread patterns. Fasteners are classified accordingly.

Screw size terminology

There are a variety of terms used to refer to the size of threaded fasteners. The automotive technician must know what these mean. Some of the most commonly used terms relating to fastener size are:

- ❑ **Major diameter**—larger diameter pertaining to screw threads. Applies to both internal and external threads.
- ❑ **Minor diameter**—smaller diameter pertaining to screw threads. Applies to both internal and external threads.
- ❑ **Bolt size**—refers to the major diameter of the bolt threads.
- ❑ **Nut size**—refers to the minor diameter of the nut threads.

- ❑ **Head size**—size of hex head measured across the flats. This is the wrench size.
- ❑ **Bolt length**—length measured from the bottom of the bolt head to the end of the threaded section.
- ❑ **Thread length**—measure of external thread length.
- ❑ **Thread pitch**—distance measured across crests of adjacent threads. Thread notes on drawings of metric fasteners give pitch in millimeters. Conventional (not metric) fasteners denote the number of threads per inch, which is the reciprocal of pitch. (Conventional threads conform to thread standards in the United States, Canada, and England.)

Thread types

Fasteners used in drive trains use three basic types of fastener threads:

- ❑ **Coarse threads**—called UNC, which stands for Unified National Coarse.
- ❑ **Fine threads**—called UNF, which stands for Unified National Fine.
- ❑ **Metric threads**—called SI, which stands for International System of Units (English translation).

Never attempt to interchange thread types. The threads will be damaged. Metric threads could be mistaken for conventional threads if they are not inspected carefully. A **thread-pitch gauge**, either conventional or metric, should be used to check any threads that you are unsure of. See **Figure 5-24**.

In addition to these thread variations, there are right- and left-hand threads used in modern vehicles. A bolt or screw with **right-hand threads** must be turned clockwise to tighten. Right-hand threads are the more common. A fastener with **left-hand threads** must be turned counter-clockwise to tighten. Sometimes, the letter *L* is stamped on fasteners with left-hand threads.

Left-hand threads are reserved for situations where rotation of a part would loosen a fastener with right-hand threads. Wheel studs and lug nuts on the left side of some vehicles have left-hand threads. When the vehicle is driven forward, normal rotation tightens rather than loosens the nuts. Hub-to-axle nuts on some front-wheel drive vehicles

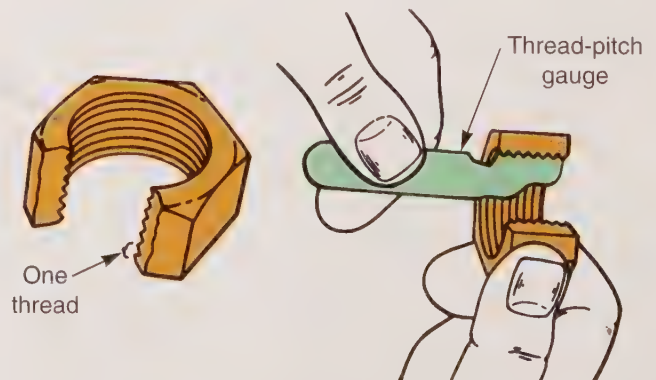


Figure 5-24. A thread-pitch gauge can be used to check thread pitch or number of threads per inch.

are also left-hand types. A few threaded adjustment devices have left- and right-hand threads. Turning the adjuster changes its length. These types of adjusters are seldom encountered on drive train parts.

Bolt grade

Bolt grade refers to the amount of pull, or tension, a fastener can withstand before it stretches or, in some cases, breaks. (Ductile materials will stretch before breaking; brittle materials will break almost right away when a tensile force is applied.) Bolt grade, then, is an indication of **tensile strength**, which is measured in pounds per square inch. Tensile strengths vary among bolts of the same size and thread pattern. Bolts are made of different metals, some stronger than others.

Bolt head markings are used to identify the tensile strength of a bolt. These markings are called **grade markings**. Conventional bolts are marked with lines, or slash marks—the more lines, the stronger the bolt. Grade 8 (6 lines) is the strongest and highest quality. Metric bolts are marked with a numbering system ranging from 4.6 to 10.9—the larger the number, the stronger the bolt. See **Figure 5-25**.

Never replace a bolt with one of a lower grade. A weaker bolt can break, causing a major part to fail. This could lead to a vehicle breakdown and presents a potentially dangerous situation.

Fastener Torquing and Tightening Sequence

Torque specifications are threaded fastener tightening values. These specifications are determined by the vehicle manufacturer. Torque specifications are critical for engine and drive train parts, as well as other vehicle parts.

It is very important to tighten all fasteners properly. An overtightened bolt will stretch and possibly break. The

threads could also be damaged, or stripped. Gaskets could be smashed or broken. An undertightened bolt could work loose and fall out. Part movement could also shear the loose bolt or break a gasket, causing leakage.

Vehicle manufacturers also provide a **tightening sequence**, or pattern, for threaded fasteners. The sequence ensures that parts are fastened evenly. Uneven tightening can cause part warping or breakage and gasket leaks. Tightening is usually done gradually and follows a criss-cross pattern, starting in the middle and working outward in steps. This results in an even pressure across the entire mating surface of the parts.

You should follow these rules to properly torque threaded fasteners:

- ❑ Pull steadily on the handle of the torque wrench. Jerking the torque wrench will cause excessive pointer deflection and invalid readings.
- ❑ Clean and oil the fastener threads before tightening.
- ❑ *Avoid* using swivel, extension, and crowfoot sockets, if possible. They will cause invalid readings.
- ❑ If using the flex-bar, or beam, type of torque wrench, look straight at the scale. Viewing from an angle produces a false reading. Do not let the pointer shaft contact any other part of the vehicle.
- ❑ Obtain and use the manufacturer's recommended tightening sequence and torque specifications.
- ❑ Torque the fasteners in steps. *Never* run one fastener up to full torque before all bolts have been partially torqued.
- ❑ Recheck torque—once after all fasteners have been fully torqued, and once after the component has been run up to normal operating temperatures and cooled off.

Removing Broken Fasteners

Occasionally, a fastener will break while it is in the part. Various methods of removing broken fasteners are shown in **Figure 5-26**. Notice that the methods used depend on whether the broken fastener extends from the part or if the break is internal.

If a fastener shaft extends from a part, several methods can be used to remove it. A slot can be cut into the shaft, and the shaft can be turned out with a screwdriver. A pipe or other metal rod can be welded to a broken fastener shaft. The rod can then be turned to unscrew the shaft. Vise grip pliers and stud pullers can be used to tightly grasp the shaft for removal.

If the fastener is broken inside the part, a screw extractor can be used. Screw extractors were briefly described in Chapter 3. Occasionally, the broken fastener can be removed by striking one edge with a chisel. This may get the fastener turning so it can be removed.

Snap Rings

A **snap ring** is a split ring used for holding parts on shafts or inside bores. The snap ring is usually used when

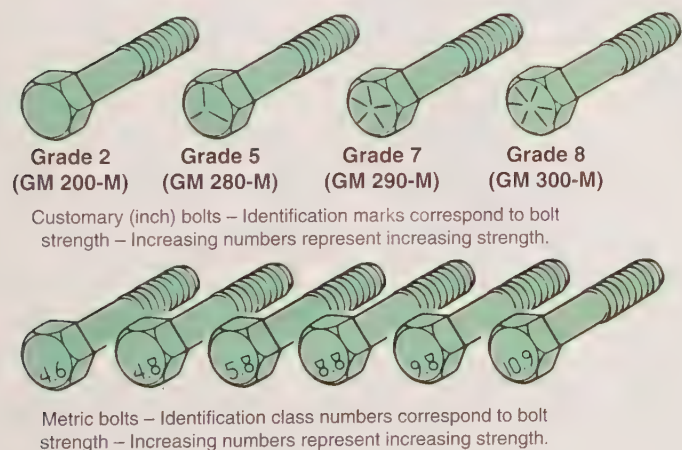


Figure 5-25. It is important to use a fastener that is strong enough. Always replace a fastener with one that is the same grade or stronger. Bolt grades can be determined by markings on the head of the bolt.

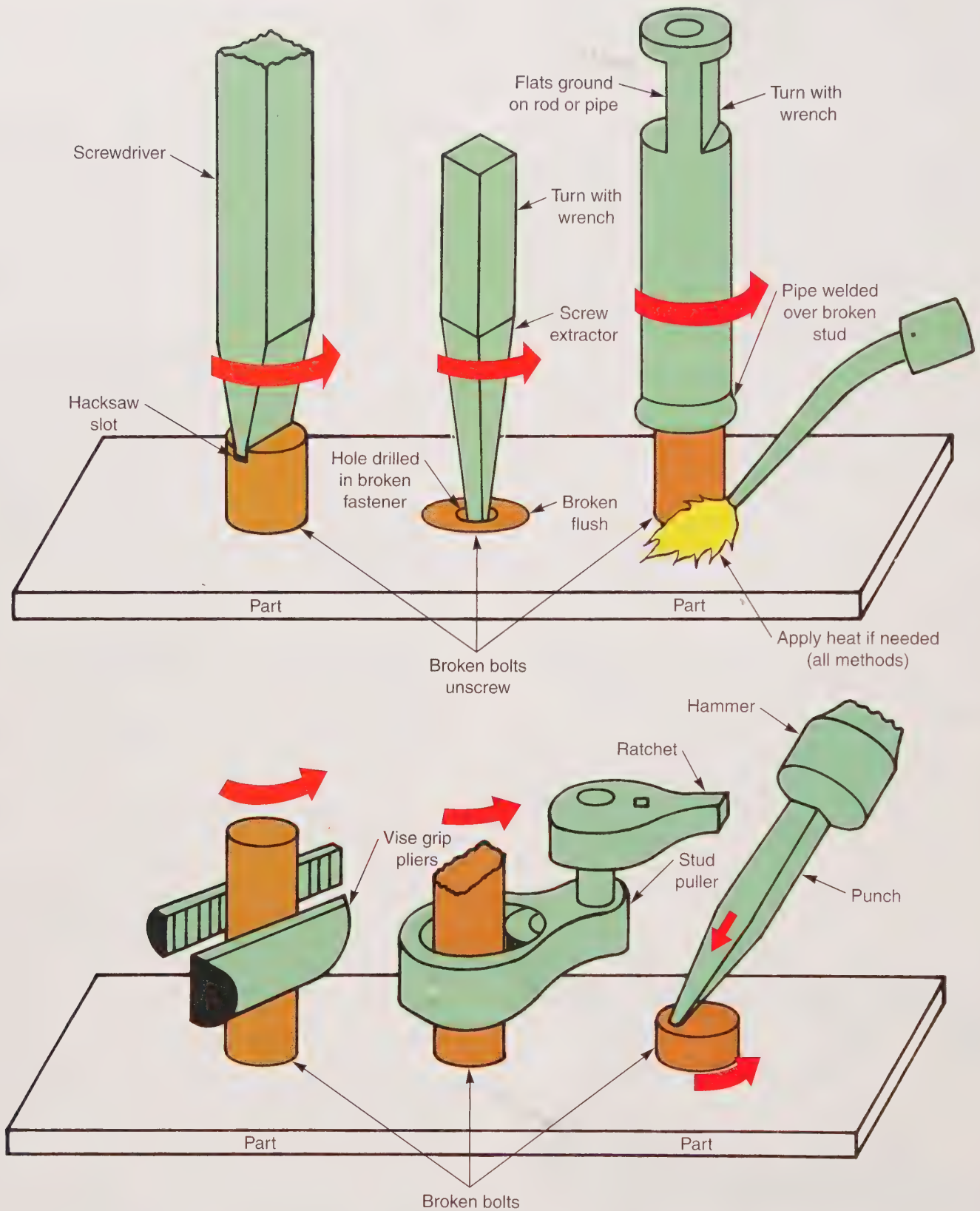


Figure 5-26. A broken fastener can be removed in many ways. Common methods are shown here. Broken fasteners are usually easier to remove if part of the fastener is sticking out of the part.

clearance will not permit the use of a threaded fastener. The snap ring fits tightly in or around a groove that is machined to accept it.

The two major kinds of snap rings are internal snap rings and external snap rings. **Figure 5-27** shows the two types. Snap rings can be removed and installed with snap ring pliers, as shown. If a snap ring is bent or distorted during removal, it should be replaced.

Drive Train Lubricants

Moving drive train parts require **lubrication**—a treatment of some sort that coats the parts to reduce friction between them. **Lubricants** are materials, usually of a petroleum nature, that provide lubrication. In addition, lubricants may serve cooling, cleaning, sealing, and power transmission functions.

Lubricants are manufactured to meet specific needs of individual drive train components, and different drive train components use different kinds of lubrication. Some components require lubricating oil, and others require grease. Transmissions, transaxles, and rear axle assemblies use oil. Universal joints and antifriction bearings are lubricated with grease.

Lubricants vary in chemical formula, or composition. They also vary in the additives they contain. **Additives** are chemicals added to improve some of the properties, or characteristics, of the original product. For example, additives may improve a lubricant's resistance to heat and reduce oil foaming. They may reduce oil oxidation, which

is the chemical breakdown of oil. Some additives, called corrosion inhibitors, help prevent the formation of acids in oils, which can damage metal parts.

The different chemical compositions and additives yield products that have different physical and chemical properties. (Physical properties are traits that do not involve chemical change; chemical properties are traits that do.)

The most obvious difference among drive train lubricants is their thickness, or resistance to flow. This physical property is technically referred to as **viscosity**. Viscosity is established through the oil-refining process and through the use of additives. The viscosity requirement of a drive train lubricant depends on the application.

Commonly, a lubricant is referred to by its weight. The weight corresponds with viscosity. A heavy lubricant is a thicker lubricant; a light lubricant is a thinner lubricant. A lubricant is given as an **SAE viscosity grade**, which classifies the lubricant by its viscosity. A typical SAE viscosity grade of motor oil, for example, would be SAE 30, called 30-weight oil. The highest grade of motor oil is SAE 50. SAE numbers get larger as viscosity increases, or as the lubricant gets thicker, or heavier.

Lubricating Oils

Lubricants that exist in a liquid state are called **lubricating oils**, or **lube oils**, for short. Several kinds of petroleum-based lubricating oils are used in the drive train. These oils serve different functions. In rear axle assemblies and manual transmissions and transaxles, the major function of the oil is to lubricate drive train parts. Of course, the oils must be compatible with, or not cause damage to, gaskets, seals, clutch and band facings, and other such parts. The most common types of lubricating oils used in drive trains are identified in the following paragraphs.

Gear oils

Gear oils are heavy oils that provide lubrication for the gears and bearings in rear axle assemblies and in manual transmissions and transaxles. These oils have high SAE viscosity grades, such as SAE 90 or 140, compared with SAE 30 or 40 for motor oils. This is done to prevent confusion when selecting engine or gear oils.

Note that gear oils are not always heavier than motor oils, and the lower grade lubricating oils are comparable to some motor oils in viscosity. Motor oils and lubricating oils are graded on different scales. This means that a gear oil and an motor oil having the same viscosity will have quite different SAE viscosity grades. For example, an SAE 90 gear oil viscosity can be similar to that of an SAE 40 motor oil. Some vehicle manufacturers even recommend the use of good quality motor oil in their transaxles, instead of gear oil.

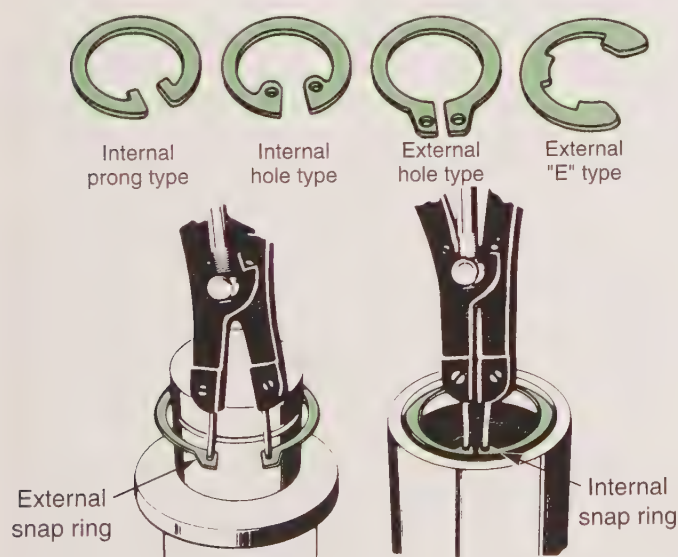
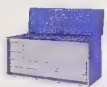


Figure 5-27. There are two kinds of snap rings—internal and external. Snap rings are often used in transmissions and transaxles.



Note: Older gear oils were mineral oils made from petroleum products. Some newer vehicles use synthetic oils, which are made from nonpetroleum products and are similar to synthetic motor oils.

Gear oils were once sold only in single weights. Today's gear oils, however, are available in multigrade versions, similar to multigrade motor oils. A gear oil marked SAE 85W-140, for instance, is rated at SAE 85 when cold. The oil contains additives that cause it to maintain enough thickness to rate SAE 140 when it heats up. Multigrade gear oils flow freely between moving parts when cold but still provide good lubrication when the parts heat up.

Gear oils contain other additives, including friction-reducing and other antiwear agents. One type of additive, in particular, prevents oil from being squeezed out from between helical and hypoid gears as they revolve. Gear oil with this type of additive is called extreme-pressure, or EP, lube. **Hypoid gear lube** is another name for it.

The American Petroleum Institute (API) has developed a gear oil rating system using GL numbers. GL1 is the lowest grade. GL1 is used only for low-speed, light-duty applications. As the GL numbers increase, the quality of the oil increases. Most gear oils for automotive use are classified GL4, GL5, and GL6.

One type of limited-slip differential uses clutches, which provide extra traction. To keep the clutches from slipping and chattering, gear oil with friction-modifying additives must be used. This oil can be used in other differentials and transmissions. Standard gear oils, however, must *never* be used in limited-slip differentials. The chemical makeup of standard gear oils will destroy the friction-modifying properties of the limited-slip gear oil. Even a small amount of standard gear oil will ruin the differential clutches. The clutches cannot be cleaned, and must be replaced. New limited-slip gear oil must be added after the differential housing is thoroughly flushed.

Most manual transmissions, manual transaxles, and rear axle assemblies have holes, capped with fill plugs, on the sides of their cases for adding gear oil. Before removing the plug to add gear oil, the area around it must be cleaned. Once the plug is removed, the gear oil may be added through the opening. The unit is full when a small amount of oil begins to drip from the opening. The fill plug can then be replaced and tightened.

Automatic transmission fluids

Some manual transmissions and transaxles require **automatic transmission fluid (ATF)**. ATF has a lower viscosity than the gear oils discussed above. Lighter oil reduces friction and power loss through the meshing gears. ATF contains special EP (extreme-pressure) additives.

There are many types of automatic transmission fluids. Use of the proper type of ATF is critical to automatic transmissions, and substituting fluids can cause

operating problems and transmission damage. Manual transmissions, however, are less discriminating, and most can be refilled with Dextron or Mercon ATF. The needed fluid type may be identified on a tag at the filler plug. Some manufacturers recommend topping off the gearbox with gear oil, even if it was originally filled with ATF.



Caution: If you are in doubt about the kind of automatic transmission fluid that a particular transmission or transaxle needs, do not guess! Check the owner's or service manual for the proper fluid.

Grease

Grease is a lubricant that exists in a solid or semisolid state. Grease provides lubrication over a wide range of temperatures. As it is water resistant, it also works to shield components from moisture and keep metal parts from rusting. Universal joints, front-wheel drive wheel bearings, clutch pilot and throwout bearings, some outer rear axle bearings, and some slip yokes are all lubricated with grease. Note that greases used for these applications are called EP greases. They provide good lubrication at extreme pressures.

There are a number of different types and grades of grease. The type of grease used depends on the application. In many cases, drive train parts can be lubricated with the same grade of grease used for front suspension fittings. In other cases, grease with a special formula tailored for a specific application must be used. You should always check the manufacturer's manual for the exact grease to use on a particular part.

Some components are designed to be greased only once, and these will be greased before they are installed on a vehicle. The grease is retained by seals. These parts usually cannot be greased, except when the entire unit is disassembled. Examples include factory-installed universal joints and most grease-lubricated rear axle bearings.

Some parts must be periodically greased. Often, these are provided with a grease fitting for injecting grease. In other cases, such as on front wheel bearings of rear-wheel drive cars, greasing is not as simple. These parts must be disassembled and cleaned before greasing, according to a specific time or mileage schedule.

Summary

Seals are used to keep lubricant in and contaminants out of components. Seals are used in transmissions, transaxles, rear axles, and other assemblies to seal rotating shafts and stationary drive train parts. Lip seals are used on rotating or sliding shafts. Ring seals are used to seal stationary parts or hydraulic pistons. There are many kinds of both lip and ring seals. Some seals are protected by dust shields in places where the seal would be exposed to dirt and water.

Boots are used to cover CV joints in front-wheel drive vehicles. The ends of the boot are fastened to the drive shafts and joint housings by straps or clamps.

Most seal defects are first noticed when the seal begins leaking. A leaking seal should be replaced as soon as possible. There are several methods of removing, inspecting, and replacing seals. When a seal is replaced, all related parts, such as shafts and housings, should be inspected and replaced if defective. In most cases, the replacement seal must exactly match the old one.

Gaskets are used to seal stationary part surfaces. Gaskets are made of relatively soft materials so they can conform to imperfections in the mating parts they seal. Many different kinds and thicknesses of gasket materials are used in a drive train. Most drive train gaskets are made of single sheets of material.

Many gasket leaks are caused by warped or damaged mating surfaces or loose fasteners. Gaskets are replaced by disassembling the parts, removing the old gasket, cleaning and inspecting the mating surfaces, and installing a new gasket. Check that the new gasket is the right one.

Drive train lubricants can be classified as either oils or greases. Oils are used in major assemblies with many interacting stressed parts. Greases are used in simpler parts where the relative movement is slow or where there are few components.

Gear oils are heavy oils used in manual transmissions, transaxles, and rear axle assemblies. Gear oils were once sold only in single weights. Today's gear oils are available in multigrade versions similar to multigrade motor oils. Multigrade gear oils flow freely between moving parts when cold but still provide good lubrication when the parts warm up to operating temperature.

API has developed a gear oil rating system using GL numbers. GL1 is the lowest grade. GL1 is used only for low-speed, light-duty applications. As the GL numbers increase, the quality of the oil increases. Most gear oils for automotive use are classified GL4, GL5, and GL6.

Gear oil with friction-modifying additives must be used in rear axle with limited-slip differentials. Standard gear oils must *never* be used in limited-slip differentials.

To add gear oil to manual transmissions, manual transaxles, and rear axle assemblies, a plug, usually on the side of the case, must be removed. Once the plug is removed, the gear oil is poured through the opening until a small amount drips from the opening, indicating that the unit is full.

Some manual transmissions and transaxles use automatic transmission fluid (ATF). ATF is thinner than gear oil. The proper fluid should always be used to avoid transmission damage.

Greases are used in some parts of the drive train, such as on universal joints and wheel bearings. In some cases, chassis grease is used. In other instances, special greases should be used. Some parts are greased at the factory. Others must be periodically lubricated through a grease fitting, or by disassembling and packing the part with grease.

Review Questions—Chapter 5

Answer the following questions using the information provided in this chapter.

1. A(n) _____ is a device that keeps a desirable element, such as a lubricant, from getting out of a component.
2. _____ are commonly used to seal rotating shafts in the drive train.
3. What is the purpose of a dust shield?
4. What are O-rings used for?
5. What, besides the seal itself, should you inspect when replacing a lip seal with many miles of service?
6. What three precautions should you observe during seal removal?
7. _____ sealers are usually resistant to heat and chemicals.
8. What are some basic rules you should observe when removing and replacing gaskets?
9. What is RTV sealer?
10. Stationary ring seals provide a kind of static seal between _____ parts.

ASE-Type Questions—Chapter 5

1. Technician A says that seals and gaskets are used to keep lubricants inside of drive train components. Technician B says that seals and gaskets are used to keep dirt and moisture out of drive train components. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
2. Each of the following statements about seals is true *except*:
 - (A) they can be used to separate two different fluids.
 - (B) they are only used to seal rotating or sliding shafts.
 - (C) boots are a type of seal.
 - (D) some seals are made of metal.
3. To ensure a sealing lip makes good contact with a rotating shaft, lip seals often use _____.
 - (A) garter springs
 - (B) leaf springs
 - (C) return springs
 - (D) torsion springs

4. Technician A says that a lip seal with a finger spring is commonly used to seal components lubricated with grease. Technician B says that a finger spring exerts less pressure on the shaft and lip than a garter spring. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
5. Technician A says that lip seals without springs are commonly used to hold back contaminants. Technician B says that lip seals without springs are used in applications where external pressure will force the sealing element against the shaft. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
6. The most common ring seal used in drive trains is the _____.
(A) square seal
(B) half-round seal
(C) triangular seal
(D) round seal
7. Technician A says that seal rings are nonpositive seals. Technician B says that seal rings can be made from metal or Teflon. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
8. Almost all seal problems show up first as _____.
(A) noises
(B) lubricant leaks
(C) shaft wear
(D) part overheating
9. Which of the following would be the *least* likely cause of low-mileage seal failure?
(A) Hardening of the sealing element.
(B) Wrong-sized seal.
(C) Improper seal installation.
(D) Damaged or bent shaft.
10. Technician A says that excessive lateral movement of a shaft may cause a seal to leak. Technician B says that an improperly sized seal will leak immediately. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
11. Technician A says that some lip seals can be removed by carefully prying them from their bore. Technician B says that some static O-ring seals can be removed by using a special puller with a slide hammer. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
12. Before seal installation, a shaft can be polished with _____.
(A) polishing compound
(B) steel wool
(C) crocus cloth
(D) fine sandpaper
13. Each of the following can be used to install a seal in a housing bore *except*:
(A) a hammer.
(B) pliers.
(C) a socket.
(D) a pipe.
14. Gaskets are *never* used to seal _____.
(A) aluminum parts
(B) oil-filled parts
(C) stationary parts
(D) moving parts
15. Each of the following is used as gasket material *except*:
(A) oil-resistant paper.
(B) aluminum.
(C) cork.
(D) ceramic.
16. A transmission cover gasket is leaking. Technician A says that bolts could have been overtightened, damaging the gasket material. Technician B says that the bolts may be loose. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
17. Technician A says that when servicing an apparent gasket leak, the first step is to clean the gasket surfaces. Technician B says that the first step when servicing an apparent gasket leak is to make sure the gasket is the cause of the leak. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.

18. Which of the following can be made relatively easily if an exact replacement is *not* available?
- (A) Gaskets.
 - (B) Lip seals.
 - (C) O-rings.
 - (D) Ring seals.
19. Hardening sealers can be used in each of the following applications *except*:
- (A) threaded fittings.
 - (B) uneven surfaces.
 - (C) permanent assemblies.
 - (D) hose connections.
20. Technician A says that RTV sealer is commonly used to make form-in-place gaskets. Technician B says that form-in-place gaskets must *never* be used in place of conventional gaskets. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
21. Anaerobic sealers will harden in the absence of ____.
- (A) moisture
 - (B) air
 - (C) oil
 - (D) gasket compression
22. Technician A says that epoxies are mixed just before being applied. Technician B says that thread-locking compounds should be used on all threaded fasteners. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
23. Each of the following is a type of threaded fastener *except*:
- (A) nuts.
 - (B) cap screws.
 - (C) snap rings.
 - (D) machine screws.
24. Each of the following is used to describe threaded fasteners *except*:
- (A) major diameter.
 - (B) thread pitch.
 - (C) head length.
 - (D) thread length.
25. Technician A says that most threaded fasteners have left-hand threads. Technician B says that the threads of metric and conventional bolts will interchange even if the head sizes are different. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
26. Technician A says that tightening bolts in the proper sequence is very important when reassembling any drive train part. Technician B says that tightening bolts to the correct torque is very important when reassembling any drive train part. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
27. Technician A says that a bent snap ring should be replaced. Technician B says that when a threaded fastener is broken inside a part, the part must be replaced. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
28. Each of the following relates to lubricant viscosity *except*:
- (A) weight.
 - (B) thickness.
 - (C) resistance to foaming.
 - (D) resistance to flow.
29. Technician A says that gear oils and motor oils are graded on the same SAE viscosity scale. Technician B says that gear oil with friction-modifying additives must be used in limited-slip differentials. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
30. Technician A says that some greaseable drive train parts are provided with grease fittings. Technician B says that some drive train parts must be disassembled to regrease them. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.



This technician is making the work area safer by cleaning up slippery oils. (Ford)



Chapter 6

Clutch Construction and Operation

After studying this chapter, you will be able to:

- ☐ Name and describe the basic parts of a clutch.
- ☐ Explain how a clutch operates.
- ☐ Describe the construction of a flywheel.
- ☐ Discuss the function and operation of the transmission input shaft.
- ☐ Describe clutch disc construction and operation.
- ☐ Name the parts and explain the operation of a pressure plate assembly.
- ☐ Describe the construction and operation of the three types of clutch linkage.

Technical Terms

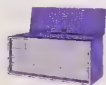
Flywheel	Torsion spring	Neutral safety switch
Transmission input shaft	Clutch cover	Clutch anticipation switch
Clutch disc	Pressure plate	Rod-and-lever linkage
Pressure plate assembly	Apply spring	Return spring
Throwout bearing	Release lever	Cable linkage
Clutch fork	Release finger	Hydraulic linkage
Clutch linkage	Diaphragm-spring pressure plate assembly	Self-adjusting cable
Clutch housing	Pivot ring	Pawl-and-quadrant assembly
Pilot bearing	Coil-spring pressure plate assembly	Master cylinder
Pilot bushing	Semi-centrifugal clutch	Slave cylinder
Transmission front bearing	Release bearing	Primary seal
Front bearing retainer	Release fork	Secondary seal
Outer disc assembly	Clutch pedal	Brake fluid
Friction facing	Free play	DOT 3
Cushion spring	Pedal reserve	DOT 4
Hub flange		Bellhousing

Introduction

This chapter discusses the parts and operation of the automotive clutch. Each major clutch part is identified, and its operation is explained. Understanding the purpose and construction of each part will make it easier for you to adjust or repair a clutch assembly. Understanding how all of the clutch parts function together will enable you to properly diagnose clutch problems.

Construction and Operation Overview

A clutch is used on a vehicle having a manual transmission or manual transaxle. The purpose of the clutch is to connect or disconnect power flow from the vehicle's engine to the rest of the drive train. A clutch is engaged, or connected, in its normal position. The engaged clutch connects the engine to the rest of the drive train, enabling the vehicle to move under its own power.



Note: For simplification, throughout this chapter, reference will be made only to manual transmissions. It should be understood that this information generally pertains to both manual transmissions and transaxles.

A clutch is disengaged, or disconnected, manually. This is done by depressing a foot pedal. The pedal is pushed in and then released, momentarily disconnecting the engine from the drive train and road to permit shifting of transmission gears. When the engine is running and the vehicle is stopped, the clutch pedal is held down to keep the clutch disengaged. Otherwise, the vehicle must be shifted into Neutral or the car's engine will stall.

Vehicle manufacturers used several kinds of clutches in the past, but most are no longer used. Most modern cars and light trucks use single-plate dry clutches. A typical single-plate dry clutch is shown in **Figure 6-1**. Its operation involves eight major parts:

- ❑ **Flywheel**—transfers engine power into the clutch. It provides a mounting surface for parts of the clutch. It also serves as an engine vibration damper and a clutch heat absorber.
- ❑ **Transmission input shaft**—transfers power flow from the clutch to the transmission.
- ❑ **Clutch disc**—is splined to and transmits power flow to the transmission input shaft. It is held against the flywheel when the clutch is engaged. See **Figure 6-2A**.
- ❑ **Pressure plate assembly**—puts spring pressure on its pressure plate to tightly hold the clutch disc against the flywheel, keeping the clutch engaged.
- ❑ **Throwout bearing**—is pushed along the input shaft into the pressure plate assembly when the clutch pedal is depressed. This causes the force from the pressure plate to be removed from the clutch disc, disengaging the clutch. The disengaged clutch is represented in **Figure 6-2B**.

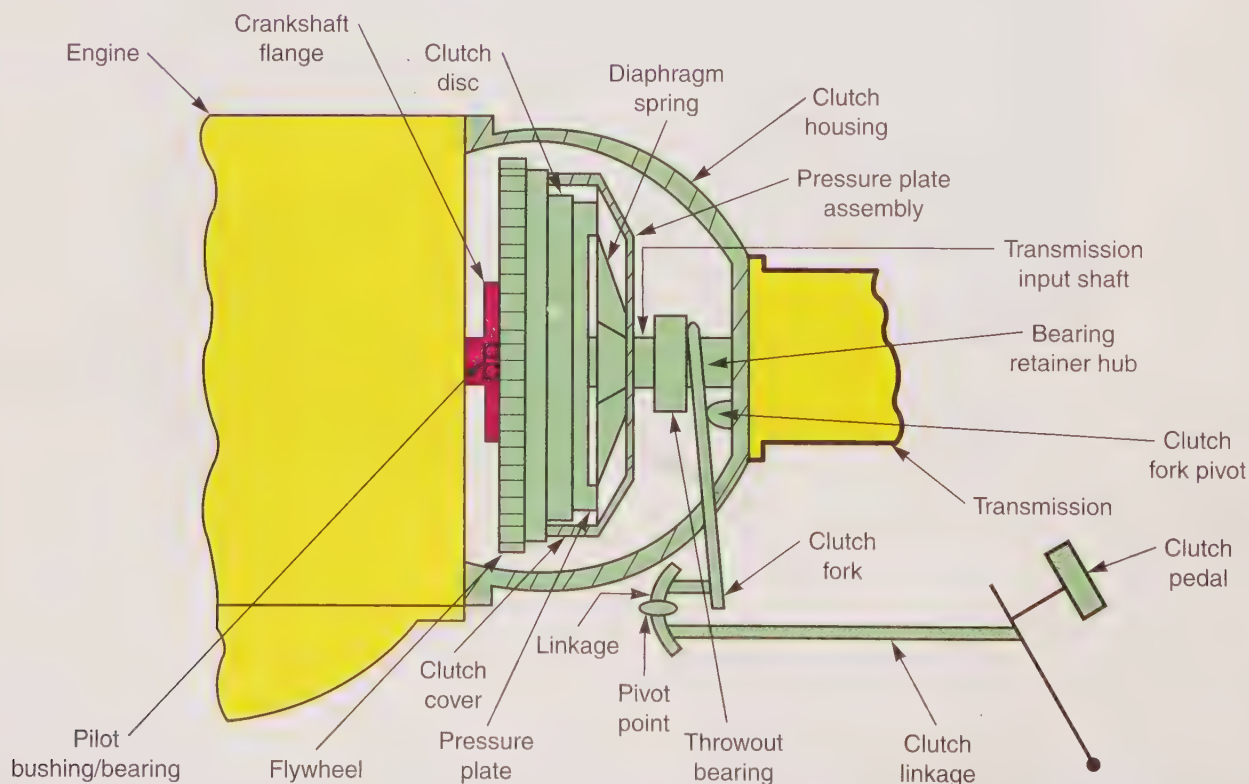


Figure 6-1. Note the relationship between various major parts of a typical single-plate dry clutch.

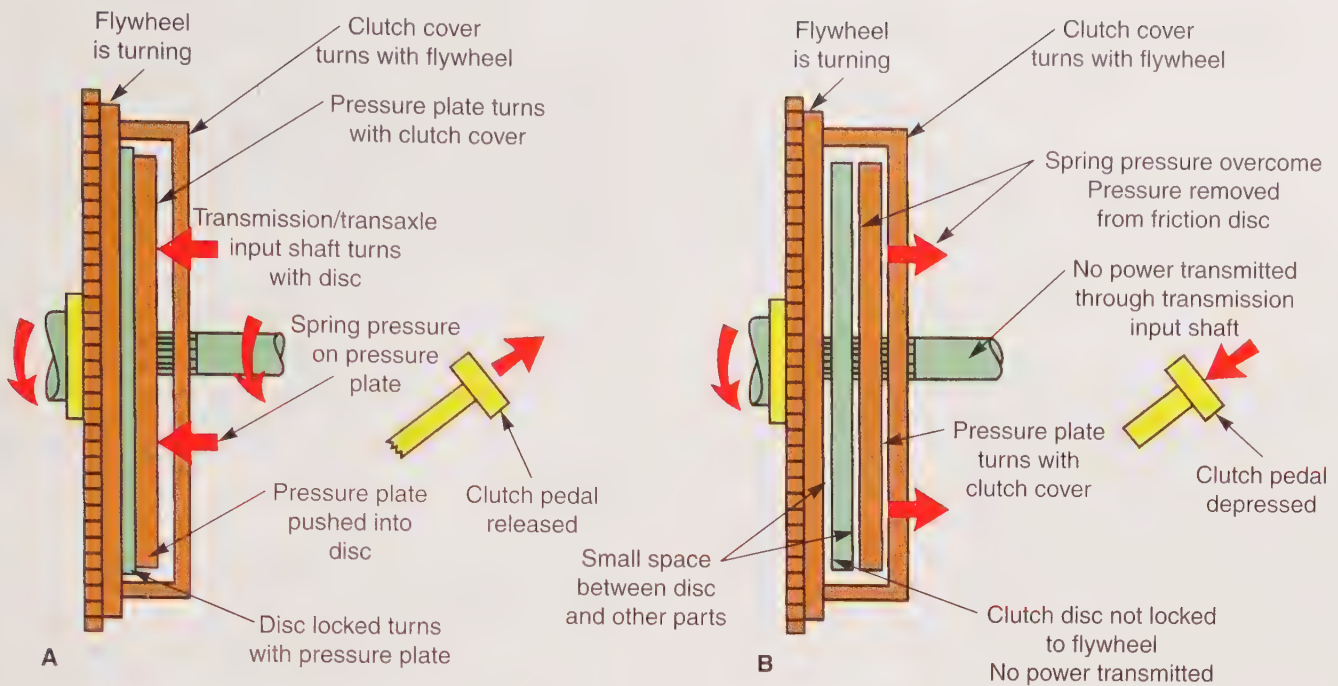


Figure 6-2. Two positions of a clutch. A—Clutch pedal out: clutch engaged. B—Clutch pedal in: clutch disengaged.

- ❑ **Clutch fork**—slides the throwout bearing into the pressure plate assembly.
- ❑ **Clutch linkage**—allows the driver to operate the clutch fork.
- ❑ **Clutch housing**—encloses the entire clutch assembly (clutch disc, pressure plate assembly, throwout bearing, and clutch fork). It protects the assembly from damage due to rocks, water, oil, and such.

In operation, the flywheel and pressure plate assembly are bolted together, **Figure 6-3**, and they revolve as a single unit. They are directly connected to the engine and turn when the engine is running.

When the clutch is engaged, the clutch disc is tightly pressed between the flywheel and pressure plate. The clutch disc, then, turns at the same speed as the flywheel and pressure plate. The clutch disc is splined to the transmission input shaft, providing a path from the flywheel, into the transmission, and on to the drive wheels. The clutch disc and transmission input shaft are turning whenever the engine is running and the clutch is engaged.

When the pressure plate moves away from the flywheel, the clutch disc is no longer pressed between the pressure plate and the flywheel. The clutch is disengaged, and power flow is interrupted. With the clutch disengaged and the vehicle at a stop, the clutch disc and transmission input shaft soon slow to a stop because of drag caused by the transmission bearing and gear loads. The period of time that it takes to stop the clutch and transmission input shaft is called the clutch spindown time. Meanwhile, the pressure plate assembly continues to revolve.

Note that the clutch disc and transmission input shaft are always turning whenever the drive wheels are turning. While shifting gears, disc and shaft are not being driven by

engine or by rotation of drive wheels through the drive train. The disc and shaft begin to slow, but they will not come to a rest before the clutch is re-engaged.

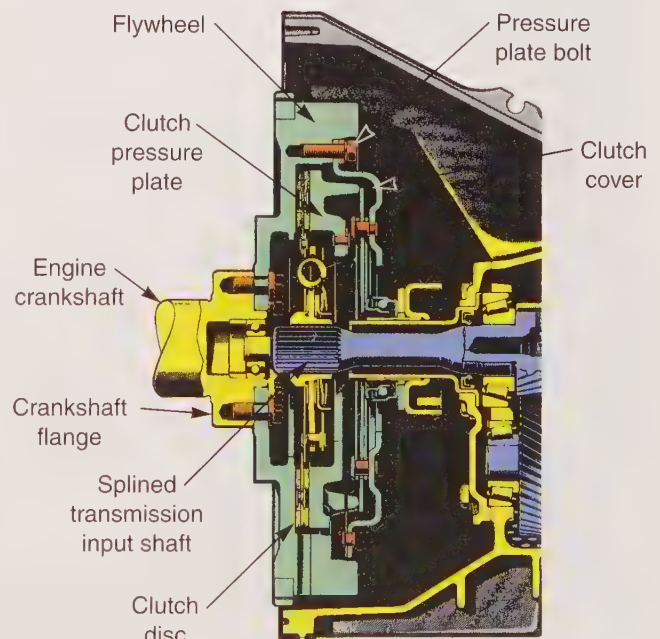


Figure 6-3. Study the relationship between the parts. Notice that the flywheel is bolted to the crankshaft flange. The clutch cover of the pressure plate assembly is bolted to flywheel. The crankshaft, flywheel, and pressure plate assembly rotate as a unit. The clutch disc is splined to the transmission input shaft. They also rotate as a unit. When the clutch is engaged, the pressure plate holds the clutch disc against the flywheel, and all parts rotate as a unit. (Mercedes-Benz)

Detailed Construction and Operation

At this point, you should be familiar with the basic parts and general operation of the clutch. Now, we will take a closer look at each of the eight major parts involved in clutch operation. This will be the focus for the remainder of this chapter.

Flywheel

The flywheel is attached to the rear of the crankshaft and turns whenever the engine is running, **Figure 6-4**. A raised ring on the crankshaft flange fits into a large hole at the center of the flywheel. Hardened bolts pass through the flywheel and are screwed into threaded holes in the crankshaft flange. The flywheel is usually made of cast iron. For engine starting purposes, a hardened-steel ring gear is usually pressed on or welded to the outside of the flywheel.

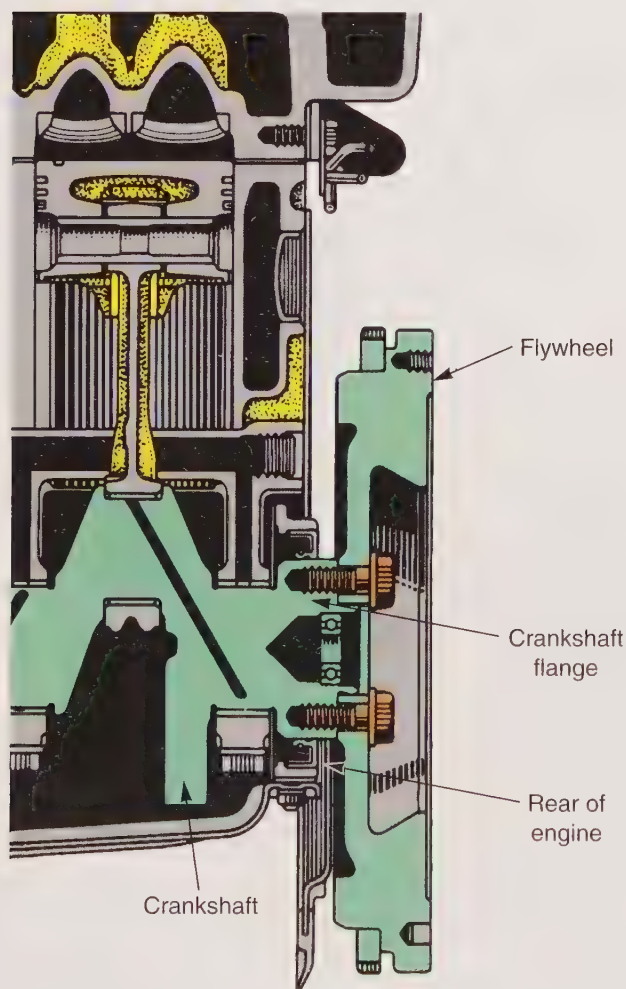


Figure 6-4. This shows the position of the flywheel in relation to the rear of the engine. The flywheel is bolted to the crankshaft flange. (Toyota)

Flywheels are heavy by design. There are two reasons for this:

- (1) Clutch operation produces heat, and the extra metal can absorb some of this heat and prevent clutch overheating under normal conditions.
- (2) The weight makes the flywheel a good damper, or inertia device, for smoothing out engine vibration.

The surface of the flywheel on the clutch side is machined to a smooth finish. This smooth area is one of the contact faces for the clutch disc. Holes are drilled and threaded into the flywheel face for installing the pressure plate assembly. Some flywheels contain pressed-in dowels, which are small metal rods, usually less than 1" (25.4 mm) long. The dowels provide for precise alignment of the pressure plate.

Transmission Input Shaft

The transmission input shaft, sometimes called the **clutch shaft**, is a long shaft that extends from the rear of the engine crankshaft to the inside of the transmission case. The shaft is made from hardened steel. It is supported by bearings at both ends. The input shaft supports the clutch disc and holds it in proper alignment with the other clutch components. Moreover, the input shaft is splined to the central hub of the clutch disc. When the clutch disc rotates, the input shaft must rotate. The input shaft transmits rotation of the clutch disc into the transmission.

The front end (about 1" [25.4 mm]) of the input shaft is smaller in diameter than other parts of the shaft. This section is sometimes called the **pilot**. The pilot fits into the clutch pilot bearing at the rear of the crankshaft.

The **pilot bearing** fits into the bore at the center of the crankshaft flange. It can be either a ball or roller bearing, or a bronze bushing, referred to more specifically as a **pilot bushing**. The bearing provides the front support for the transmission input shaft. Note that it should be lubricated whenever the transmission and clutch are removed from the vehicle.

The input shaft diameter increases beyond the pilot, and the next section contains the external splines that mate with the clutch disc splines. The splines allow slight forward and rearward movement of the clutch disc on the input shaft. This sliding action allows the clutch disc to move away from or against the flywheel when it is disengaged or engaged.

After the splined section of the shaft is the section for the **transmission front bearing**—an antifriction bearing that provides the rear support for the input shaft. The shaft extends through the front bearing and into the transmission. The rear of the shaft contains the transmission main drive gear, which drives the other gears of the transmission.

The front bearing is held in place by a bearing retainer. The **front bearing retainer**, as it is called, also serves as a hub for the clutch throwout bearing and provides a sliding surface for the bearing assembly. The different sections of the input shaft are shown in **Figure 6-5**.

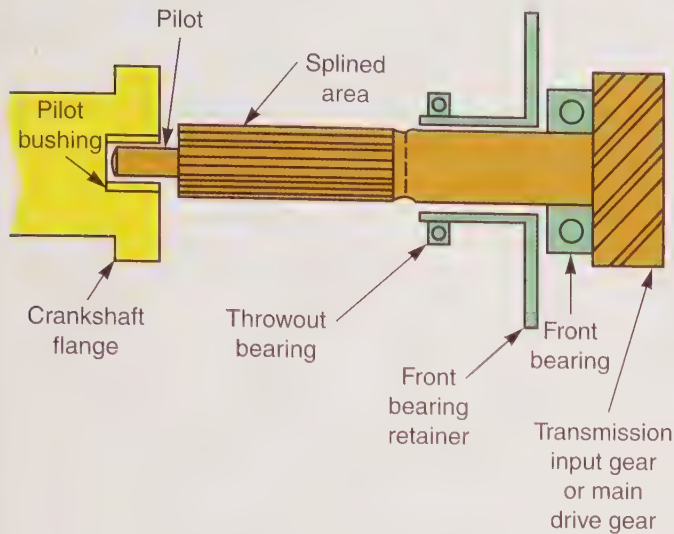


Figure 6-5. Note the different sections along the transmission input shaft.

Clutch Disc

The clutch disc, also called a **friction disc**, is installed between the flywheel and the pressure clutch plate. The job of the disc is to transmit power from the flywheel to the transmission input shaft. It must transmit this power with little or no slippage, allow for smooth engaging and disengaging, and stand up to high temperatures. The clutch disc is made up of an outer disc assembly and a central hub flange. See **Figure 6-6**.

Outer disc assembly

The **outer disc assembly** is the portion of the clutch disc consisting of a plate of thin steel sandwiched between a friction material called the clutch disc **friction facing**. The facing makes up the part of the disc that actually contacts the flywheel and pressure plate. Friction facings are made of materials that will operate satisfactorily under high temperatures. Materials similar to those found in brake linings are often used. For added strength, the friction materials may be reinforced with wire mesh, or screening.

The friction facing may be held to the steel plate in a couple of different ways. Sometimes, the facing is bonded to the steel plate with high-temperature glue. Often, the facing is riveted to the steel plate. The rivets are usually made of brass, which is a relatively soft metal. Using brass rivets reduces damage to the flywheel and pressure plate should the clutch facing wear down to the rivet heads.

The friction facing is often divided into segments. See **Figure 6-7**. The segments help the clutch to engage smoothly by spreading the friction forces over many small areas instead of one large area. The gaps between the segments provide a suction break between the mating surfaces, which keeps the parts from sticking when the clutch is disengaged. The gaps also provide for more efficient heat removal.

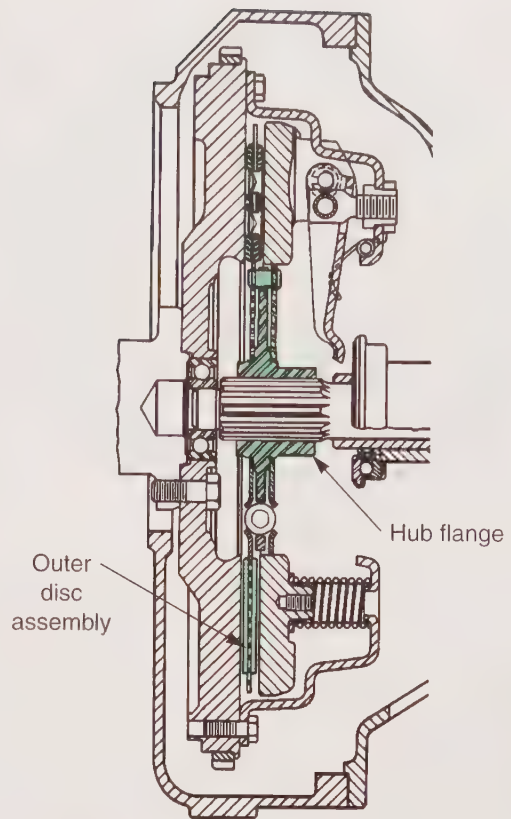


Figure 6-6. The clutch disc, made up of an outer disc assembly and a central hub flange, is installed in the clutch between the flywheel and pressure plate. (General Motors)

Most clutch discs contain **cushion springs** under the friction facing. These springs are flexible plates with a slight wave or curve. The plates compress when the clutch is engaged. They absorb some of the shock of engagement.

Hub flange

In the center of the clutch disc is a splined hub. The hub splines engage the splines on the transmission input shaft. This **hub flange**, as it is called, is usually made of cast iron.

The hub flange and outer disc assembly are riveted together. The rivets are solidly mounted to the hub flange and pass through slotted holes in the outer disc. Coil springs, called **torsion springs**, keep the rivets positioned to one end of the disc slots, toward the direction of rotation. **Figure 6-7** shows the location of the torsion springs.

Engine power must actually go through the springs to get from the disc to the hub flange. When the clutch is engaged, engine power slightly compresses the springs. As the clutch is being engaged, this will cause the rivets to move in the slotted holes. This spring action cushions the engagement of the clutch. The springs will also smooth out vibrations from the engine.

Note that there are a few clutches intended for heavy-duty use that may not have torsion springs. Also, note in **Figure 6-7** that two of the springs appear to be missing. This is done deliberately. On many clutch discs used with smaller engines, fewer springs are needed.

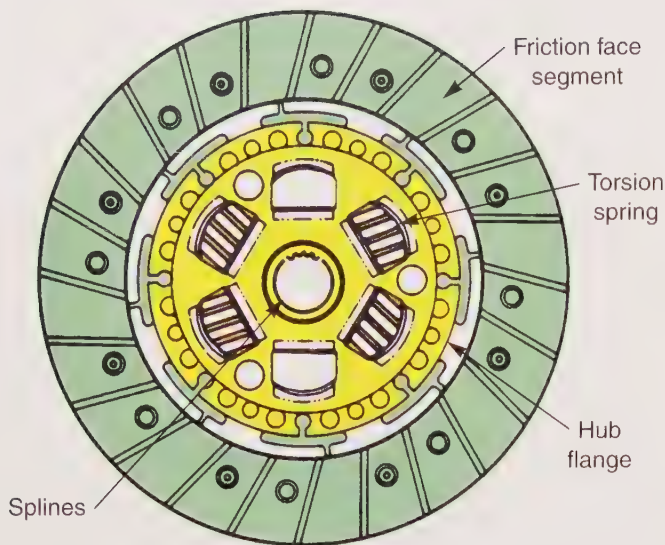


Figure 6-7. Study the various parts of the clutch disc. (Chrysler)

Pressure Plate Assembly

The pressure plate assembly is made up of a cover, a pressure plate, and springs. Refer to **Figure 6-8**. The **clutch cover** is bolted to the flywheel; it turns with the flywheel. In its normal position, the **pressure plate** locks the friction disc between itself and the flywheel, and the entire assembly is driven at flywheel speed. **Apply springs** between the

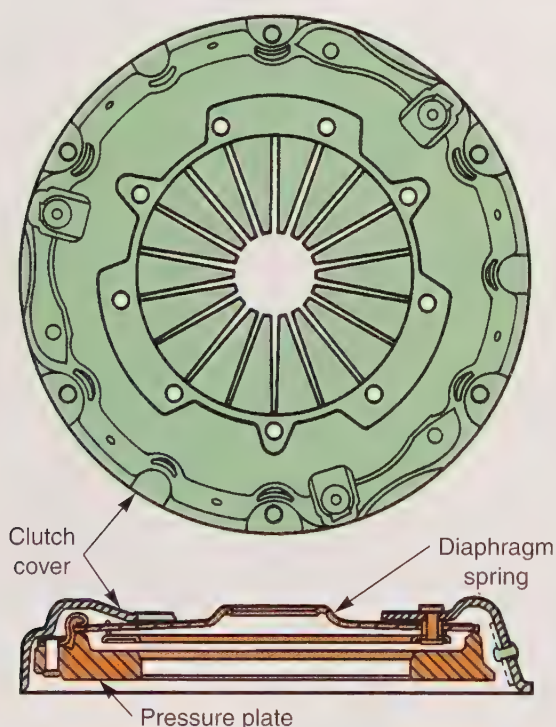


Figure 6-8. Three major components of the pressure plate assembly are shown here. Study the relative positions of the clutch cover, pressure plate, and spring. Note that this pressure plate assembly uses a diaphragm spring. (Chrysler)

cover and pressure plate hold the pressure plate against the clutch disc. To unlock the clutch disc, the plate is moved away from normal position by the driver. This happens by actuating the **release levers** or **release fingers** contained within the assembly, thus backing off the pressure plate.

The flywheel and pressure plate assembly are balanced at the factory. The parts have special reference markers. These markers are to be matched when reassembling the unit. This is to prevent an imbalance in the drive train. Sometimes, dowels or an irregular bolt pattern are used to prevent improper installation.

Clutch cover

The clutch cover encloses the pressure plate assembly. It is usually made of heavy steel plate. Holes are located in the cover for rivets or bolts that hold the assembly together or attach the cover to the flywheel. The cover contains various slots and other openings that allow air to circulate inside of the assembly. The air helps to remove heat from the pressure plate assembly.

Pressure plate

The pressure plate is the part of the assembly that actually presses against the clutch disc. The plate is a ring-shaped disc that is made of thick cast iron. The weight of the pressure plate assists the flywheel in heat absorption and vibration damping. The plate is roughly the same size as the outer disc assembly of the clutch disc. The transmission input shaft passes through a center hole in the disc. The size of the hole allows for clearance with the torsion springs. The side of the pressure plate away from the cover is flat and smooth. This side contacts the clutch disc facing area. The other side is machined for installation of the springs and release levers.

Apply springs

The apply springs provide the pressure that holds the pressure plate to the clutch disc. This pressure must be overcome to free the clutch. The springs must be strong enough to keep the clutch disc applied but still allow the driver to disengage the clutch without excessive pedal effort. The two types of apply springs used are diaphragm springs and coil springs.

The **diaphragm-spring pressure plate assembly** uses a single diaphragm spring. See **Figure 6-9**. The diaphragm spring is made of spring steel. It is formed in the shape of a dish. This combination produces the spring effect. Radial slits in the diaphragm form numerous release fingers. These act as release levers to remove the holding power of the spring action. A central hole permits the transmission input shaft to pass through.

The diaphragm spring makes contact with the pressure plate at the outer rim. There are two rings built into the pressure plate assembly. They are located near the outer rim. The rings are called **pivot rings**. There is one pivot ring on each side of the diaphragm spring. The rings are held in position by retaining rivets that extend through the clutch cover.

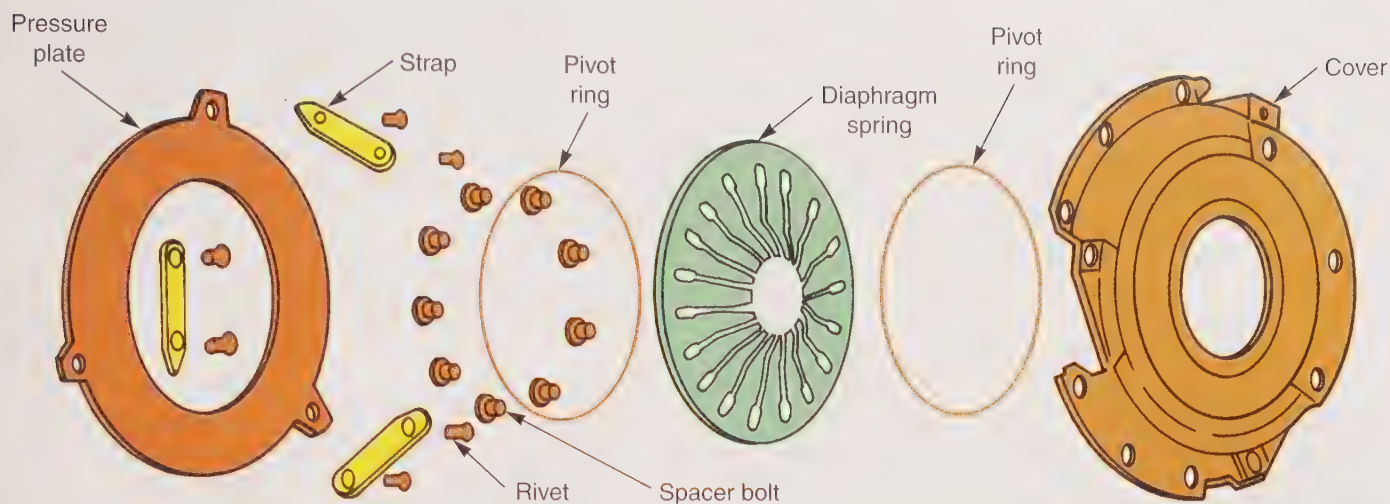


Figure 6-9. Diaphragm-spring pressure plate assembly. (Luk)

When the pressure plate is in its normal, or engaged, position, the diaphragm spring is in a compressed state. The dish-shaped spring becomes nearly flattened by action against the pressure plate rim and outer (cover-side) pivot ring. This happens as force is applied at the pivot ring by tightening the cover bolts. The pressure plate is pushed into the clutch disc because of the resulting spring pressure, **Figure 6-10A**.

To disengage the clutch, the throwout bearing is pushed inward, toward the pressure plate assembly and against the release fingers, **Figure 6-10B**. The diaphragm pivots on the inner pivot ring. When the center of the diaphragm is pressed inward, the outer rim pivots outward, or toward the clutch cover. This action removes the pressure on the clutch disc.

Meanwhile, the pressure plate is drawn back with the outer rim of the diaphragm. Contact between the pressure

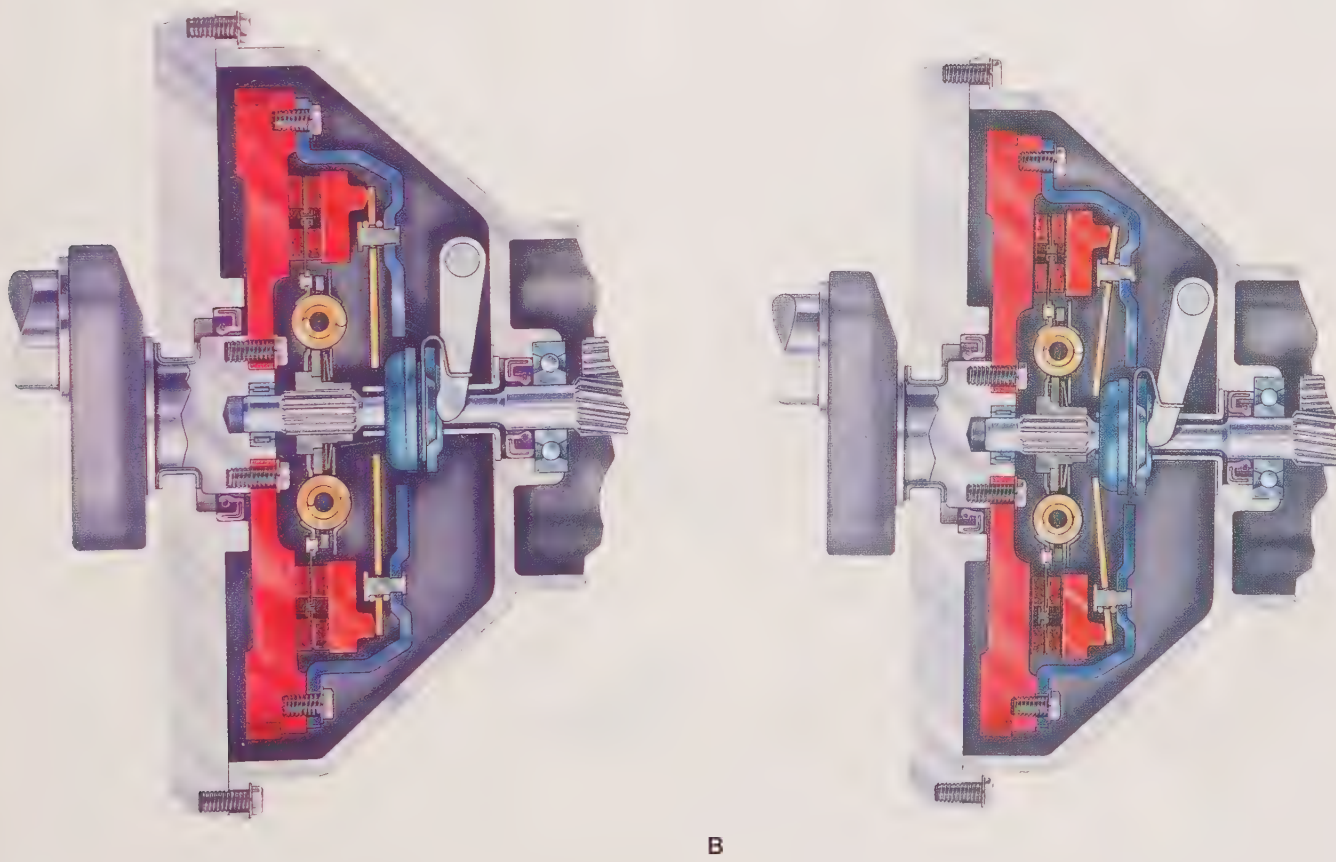


Figure 6-10. Visualize the action with a diaphragm clutch assembly. A—The pressure plate spring tightly holds the clutch disc between the flywheel and pressure plate. The clutch is engaged, and power can flow from the engine to the transmission. B—The pressure plate is not pressing the clutch disc against the flywheel. The clutch is disengaged. Power flow is interrupted. (Luk)

plate and diaphragm is maintained by springs (not shown in **Figure 6-10**) called holddown springs, or retracting springs. In some designs, the springs are bolted or riveted at one end to the pressure plate, and the other end clips over the outer rim of the diaphragm. In other designs, the springs consist of flexible drive straps made of spring steel. One end attaches to the pressure plate; the other attaches to the clutch cover. The springs or straps cause the pressure plate to pull away from the clutch disc when the diaphragm is retracted. Whatever the design, the pressure plate and the rest of the assembly continue to rotate with the flywheel.

When the throwout bearing is moved back outward, the diaphragm returns to its original (compressed) position. The pressure plate, once again, applies pressure to the clutch disc, and the clutch is re-engaged.

The **coil-spring pressure plate assembly** uses large coil springs. The springs are pressed between the pressure plate and the clutch cover. There may be as few as four springs, but most assemblies have at least ten. The larger the engine and vehicle, the more springs needed. The coil springs are made of hardened spring steel. They can withstand heat and pressure. The relative position of the springs between the cover and pressure plate is shown in **Figure 6-11**.

In this type of assembly, pressure is removed from the clutch disc by pulling the pressure plate back against spring pressure. Release levers are used for this operation.

Release levers

Release levers are used in a coil-spring pressure plate assembly to overcome spring pressure and pull the pressure plate away from the friction disc. The levers are arranged radially and are hinged to the clutch cover. Most pressure plates use three release levers. The levers pivot on their hinges, just as the diaphragm spring pivots on its pivot rings.

Each release lever is connected at one end to the rear of the pressure plate. The lever is actuated by contact with the throwout bearing at the other end. When the throwout bearing contacts the release lever, the lever moves inward, pivoting on its hinge. This action pulls the pressure plate away from the friction disc, further compressing the coil springs in the process. A typical release lever is shown in **Figure 6-12**.

Most release levers have additional weight added to their outer ends. The weights are situated such that when

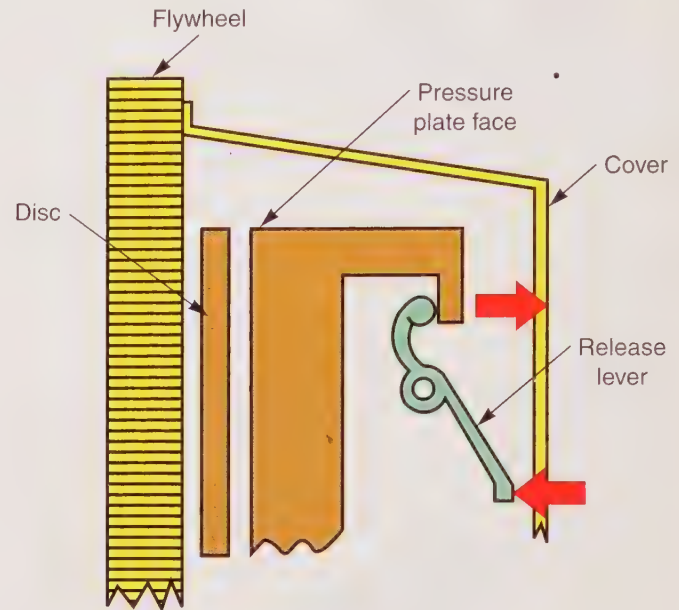


Figure 6-12. Release levers are used on pressure plates that use coil springs. To release the clutch, the lever is pushed in. It pivots on its hinge and pulls the pressure plate away from the clutch disc. Although one lever is shown, most pressure plates use three release levers.

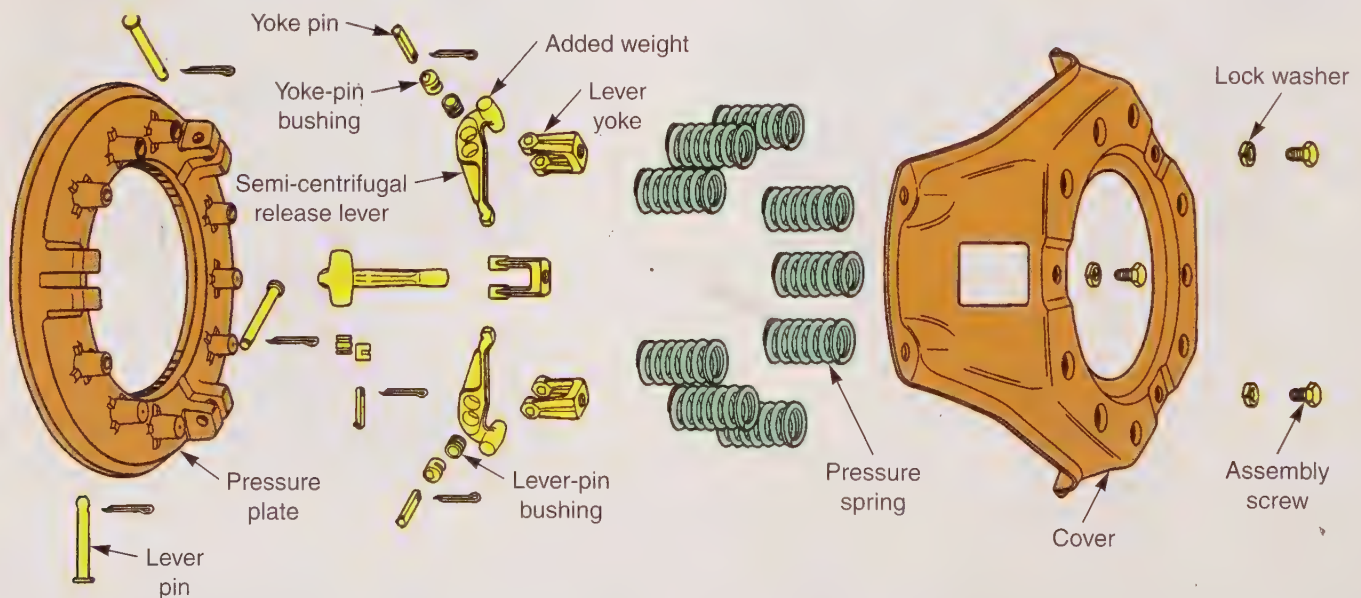


Figure 6-11. Coil-spring pressure plate assembly. (Luk)

the pressure plate assembly is rotating, they tend to be thrown out to a larger diameter. The resulting action causes the weights to exert additional pressure against the pressure plate. This helps the springs to hold the friction disc tightly at high engine speeds. As a result, lighter springs can be used making it possible to operate the clutch with less effort. Clutches that use this kind of arrangement are called **semi-centrifugal clutches**.

Throwout Bearing

The throwout bearing, or **release bearing**, applies force to the release levers or fingers. In so doing, it disengages the clutch. The throwout bearing is designed to operate with minimum friction between rotating and stationary points of contact.

The throwout bearing assembly consists of the bearing itself and a collar, or sleeve. The bearing is a thrust-type ball bearing, designed to sustain axial loads. It is similar to other thrust bearings in that bearing races are situated axially with respect to each other. The bearing, in some cases, is pressed on a sleeve, or collar. In other cases, it is an integral part of the collar. See **Figure 6-13**.

The collar slides on the smooth hub that is part of the transmission front bearing retainer. It can rotate on the hub, also. The collar is machined to fit the clutch fork, which operates the throwout bearing assembly, and it incorporates a retainer spring to hold the clutch fork in place and reduce rattle. The entire throwout bearing assembly is greased at the factory, and, except for some heavy-duty bearings, it cannot be regreased without removing the transmission.

As the throwout bearing contacts the turning release levers or fingers, the affected bearing race will begin to rotate while the sleeve is retained by the clutch fork. In addition, the sleeve may rotate on the retainer hub, thereby

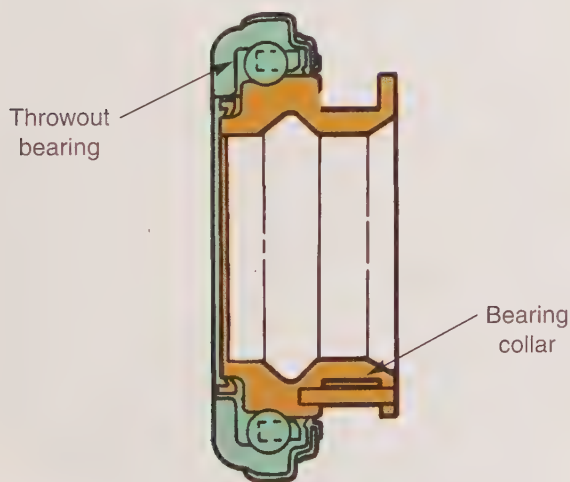


Figure 6-13. Sectional view of a typical throwout bearing assembly in which the bearing is an integral part of the sleeve. When installed, the assembly will slide over the transmission bearing retainer hub. The hub is machined to allow free movement of the throwout bearing. (General Motors)

absorbing some of the shock when the throwout bearing first contacts the spinning pressure plate assembly.

When the clutch pedal is released, the clutch return springs pull the clutch fork and throwout bearing away from the release levers or fingers. In the engaged position, the throwout bearing does not contact any part of the pressure plate assembly. **Figure 6-14** shows the relative positions of the clutch disc, pressure plate assembly, throwout bearing, and clutch fork.

Clutch Fork

The function of the clutch fork, or **release fork**, is to transfer the force of the clutch pedal and linkage to the throwout bearing. Clutch fork components are composed of hardened steel, pressed into the necessary shape. There are two types of clutch forks.

The lever type clutch fork pivots on a stationary ball stud that is mounted inside the clutch housing. See **Figure 6-15**. The fork is held to this ball stud with a spring clip. Since the clutch fork works on the lever principle, the placement of the pivot point (ball stud) determines the amount of force multiplication relative to the clutch pedal. If the pivot point is close to the throwout bearing, less pedal pressure will be needed to release the clutch. The pedal, however, will have to move a longer distance. If the pivot point is farther away from the throwout bearing, the pedal does not need to travel as far, but will be harder to depress. Placement will also vary depending on the type of clutch release mechanism used.

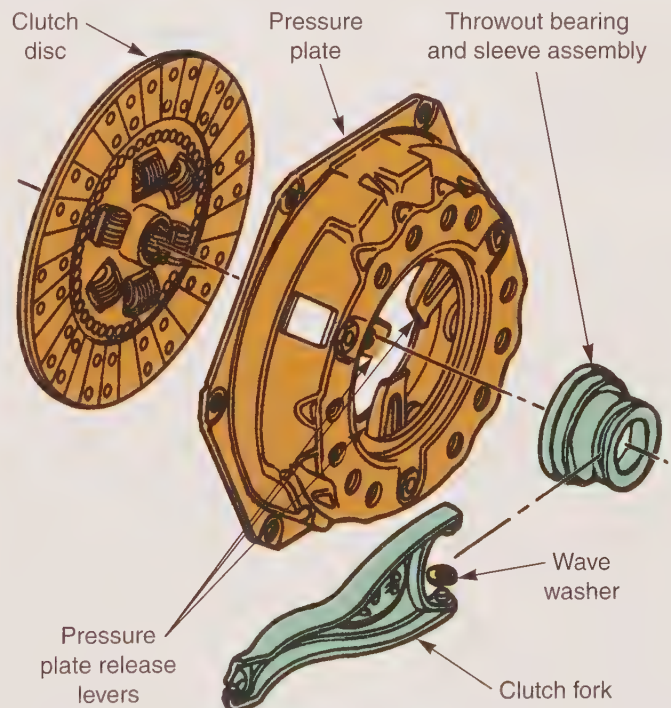


Figure 6-14. Note the position of the throwout bearing in relation to the other clutch parts. The throwout bearing, which controls operation of the clutch, is operated by the clutch fork. (Chrysler)

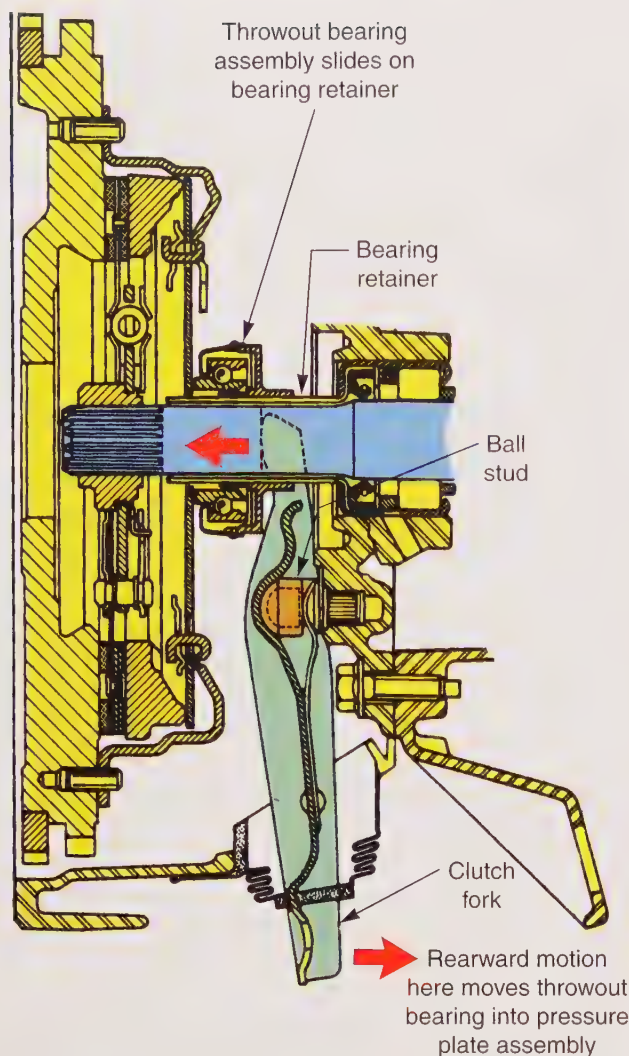


Figure 6-15. A lever-type clutch fork. Note the relationship between the clutch fork, ball stud (pivot point), and throwout bearing. (Chrysler)

When the outer end of the fork is moved toward the rear of the clutch housing, the inner end will move inward and push the throwout bearing against the clutch release levers or fingers. When the clutch pedal is released, the clutch fork and linkage, aided by return springs, pulls the throwout bearing away from the pressure plate assembly.

The other type of clutch fork is installed on a shaft that extends through the clutch housing. Depending on the installation, the shaft may pass over or under the transmission input shaft and throwout bearing. The fork extends away from its shaft. It is moved inward when the shaft is turned by the clutch linkage. This kind of clutch fork is shown in **Figure 6-16**.

The clutch is disengaged in the same manner as it is by the lever-type fork. The clutch fork pushes the throwout bearing inward. The throwout bearing frees the pressure plate assembly. To engage the clutch, the clutch linkage pulls the fork and throwout bearing away from the pressure plate assembly.

Clutch Linkage System

The pressure plate apply springs are strong. They must be strong to hold the friction disc firmly and prevent slipping when the clutch is engaged. If not overcome by external pressure, the springs in the pressure plate assembly would hold the clutch in the engaged position at all times. Therefore, some strong force must be found to disengage the clutch. This force is provided through the clutch linkage system. The clutch pedal and linkage are considered part of this system. In addition, some manufacturers consider the clutch fork a part of the clutch linkage system.

Clutch pedal

Vehicle manufacturers decided many years ago that the best way to overcome spring pressure in order to disengage the clutch is with a foot-operated **clutch pedal**. The clutch fork is operated by the driver's foot via the clutch pedal. This action moves the linkage that moves the clutch fork.

The clutch pedal is a lever with a rubber pad at one end. The other end of the pedal is attached to linkage that connects the pedal to the clutch fork. The pedal is mounted on a bracket under the dashboard. (This bracket may also hold the brake pedal.) The pedal pivots on metal or plastic bushings, which reduces noise and wear. When foot pressure is released, the pedal, with the help of the clutch return springs, is returned to its fully released position.

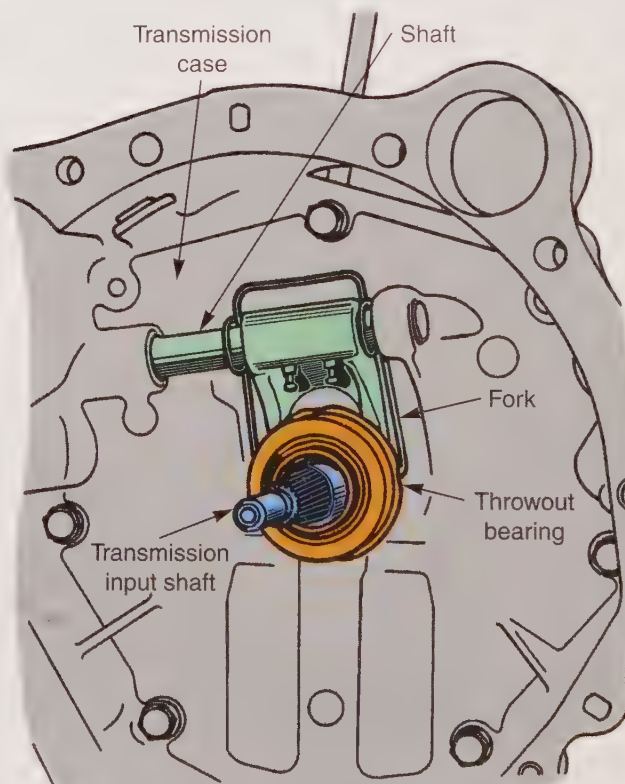


Figure 6-16. A shaft-type clutch fork. The shaft turns, moving the fork and throwout bearing forward. (Renault)

The placement of the pivot point determines the amount of force multiplication provided by the lever. The force applied to the clutch pedal is multiplied at the expense of distance. Note that the clutch pedal must be moved about 5" or 6" (125 or 150 mm) to move the throwout bearing less than 1" (25 mm). The force applied to the throwout bearing is five or six times that exerted on the pedal.

Two terms associated with the clutch pedal are free play and pedal reserve. **Free play**, also called **free travel**, is the distance that the pedal will travel when first depressed before the slack in the linkage is taken up and any appreciable resistance is felt by the driver. Once the slack is eliminated, further pedal travel causes the throwout bearing to contact the pressure plate and begin to disengage the clutch. There is usually about 1" (25 mm) of free play in the pedal. This distance is often determined by the distance between the throwout bearing and release levers or fingers when the clutch pedal is fully released.

Free play should not be confused with **pedal reserve**. This is the amount that the pedal can still be depressed beyond the point where the clutch is fully disengaged. The throwout bearing continues further inward, and the pressure plate is moved outward further than is actually needed for full disengagement. When a specification for pedal reserve is given, it usually is about 1" (25 mm). Free play and pedal reserve are depicted in **Figure 6-17**.

Clutch pedal electrical connections

Almost every clutch pedal assembly contains some electrical switches. The **neutral safety switch** is always attached to the pedal linkage. Some vehicles have a **clutch anticipation switch** that signals the vehicle computer when the clutch is depressed. The computer reduces throttle

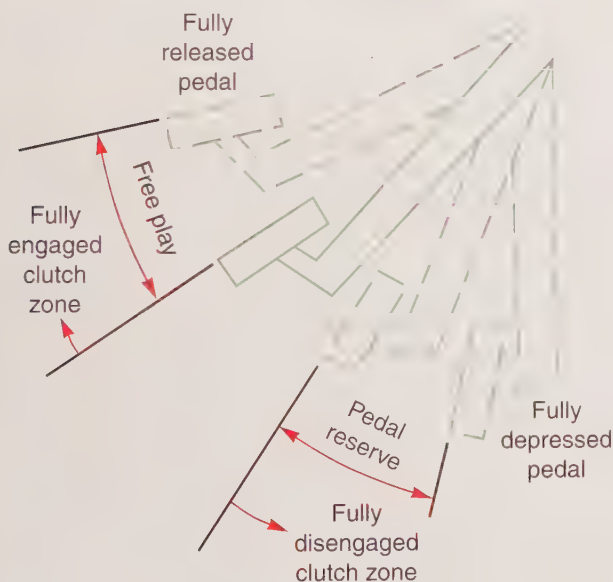


Figure 6-17. Free play is the distance the clutch pedal will move before the throwout bearing contacts the pressure plate. Pedal reserve is the distance the pedal can be depressed after the clutch is completely disengaged.

opening to keep the engine from speeding up excessively when the clutch is depressed.

Clutch linkage

Clutch linkage transmits the force applied to the clutch pedal to the clutch fork. There are three basic kinds of clutch linkage:

- ❑ **Rod-and-lever linkage**—a mechanical clutch linkage that depends on a set of rods and levers to transmit movement from pedal to clutch fork.
- ❑ **Cable linkage**—a mechanical clutch linkage that transmits motion by means of an enclosed cable between the pedal and the clutch fork.
- ❑ **Hydraulic linkage**—uses the clutch pedal to develop hydraulic pressure. The hydraulic pressure transmits movement to the clutch fork.

All clutch linkages must have some method of adjustment. As the clutch disc wears, the pressure plate must move further to compensate. This causes the release levers or diaphragm spring to pivot further, moving inward at the pressure plate and outward at the throwout bearing. As a result, the release levers or fingers will move closer to the throwout bearing, and the clutch free play will decrease. If the clutch wears enough, the free play will disappear completely, and slippage could result. To prevent this, provisions are made for adjusting the linkage so that the throwout bearing can be moved further away from the release levers as parts wear.

Rod-and-lever linkage, shown in **Figure 6-18**, has a pushrod attached to the clutch pedal. The pushrod moves a lever called the bellcrank. The bellcrank operates another pushrod, or release rod. The release rod pushes the clutch fork rearward to operate the throwout bearing. The clutch fork pivot point lies between the throwout bearing and release rod. Pushing on the clutch fork causes the throwout bearing to move inward. Smooth operation of the entire linkage depends on proper lubrication and alignment of the pivot points.

The release rod is located next to the clutch housing. Its effective length can be changed to adjust the clutch free play. Adjustment is usually made by loosening the release rod adjusting locknuts and shortening the release rod. The locknuts are then retightened. Shortening the rod moves the throwout bearing away from the release levers or fingers to increase the free play, which has diminished over time.

Springs will be mounted along the linkage in various locations. **Return springs** function to return the clutch fork and linkage to their normal, or released, positions. Other springs may be used for holding certain parts in proper position.

Cable linkage utilizes a cable to transfer pedal pressure to the clutch fork. To move the clutch fork, the clutch cable is pulled by pressure on the clutch pedal. (This action is opposite from that of a rod-and-lever linkage, wherein the clutch fork is pushed by depressing the clutch pedal.) When foot pressure is removed from the clutch pedal, the return springs and pressure plate springs return

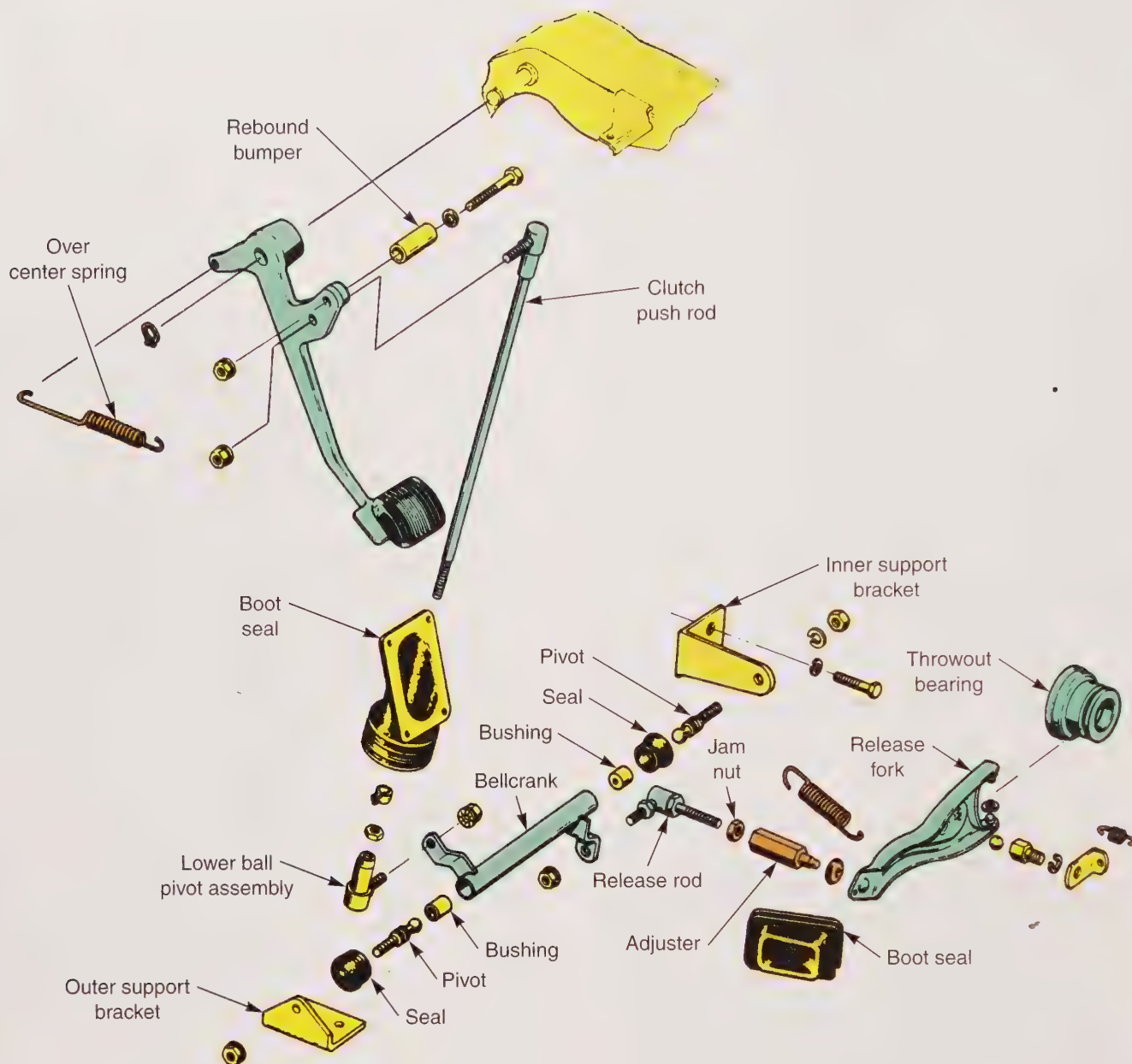


Figure 6-18. This is an exploded view of a rod-and-lever linkage. Notice how the rods and levers fit together to operate the clutch. (Chrysler)

the pedal to the fully released position. A simple cable release system is shown in **Figure 6-19**.

With the basic lever-type clutch fork, the cable pulls the clutch fork forward to operate the throwout bearing. The throwout bearing lies between the cable and pivot point. Thus, pulling on the clutch fork causes the throwout bearing to move inward. A return spring, which directly opposes the cable, pulls back on the clutch fork when the pedal is released to disengage the throwout bearing.

Cable linkages have a cable housing, which serves as a guide and protective cover for the cable. The housing holds lubricant to prevent cable sticking. This housing is sometimes called a sheath. Cable brackets are located along the length of the sheath to hold the cable in the proper position.

A means for adjusting the cable is located at one end of the cable. The adjustment procedure is similar to that of the rod-and-lever linkage. The effective length of the cable housing is changed to adjust clutch free play. The length is changed by repositioning an adjusting nut. In most cases, free play is increased by shortening the effective length of the cable housing, thereby feeding more cable to the clutch fork. This causes the throwout bearing to move further away from the pressure plate assembly.

Some cable linkages have a provision for self-adjustment to compensate for wear, usually occurring in the cable or clutch disc. The **self-adjusting cable** operates through a **pawl-and-quadrant assembly**, **Figure 6-20**. The pawl is a toothed link. It is used to engage teeth that are built into the quadrant, which is a pivoting ratchet. It is in

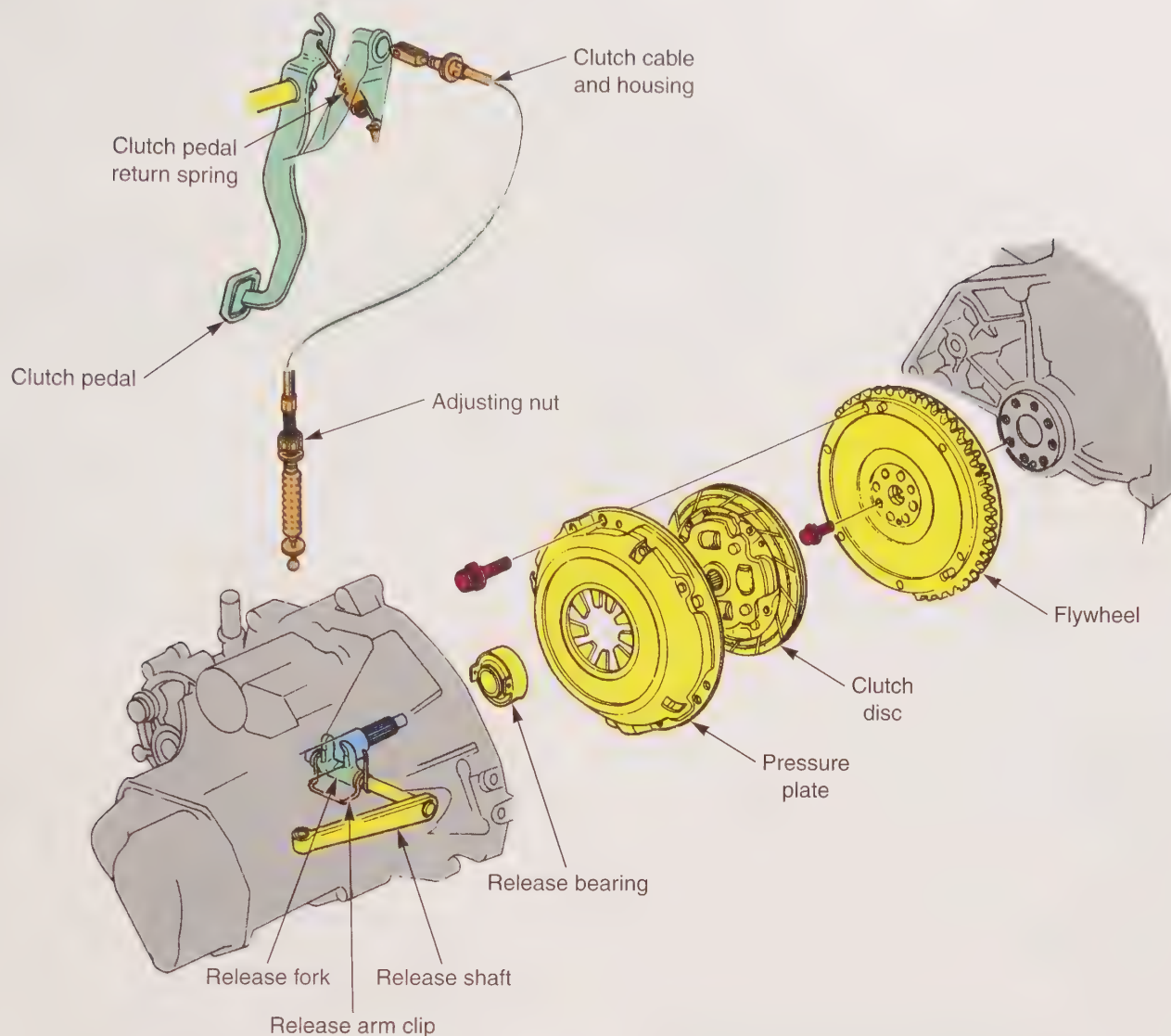


Figure 6-19. A simple cable linkage is shown here. Pushing the clutch pedal pulls the cable, which operates the release fork. (Honda)

the shape of a quarter-circle. It pivots on the pedal bracket. The assembly is mounted under the dashboard. In a typical assembly, the end of the clutch cable is attached to the far end of the quadrant, and the pawl and quadrant are spring loaded. See **Figure 6-21**.

When the clutch pedal is depressed, the pawl engages the quadrant teeth. The quadrant moves about its pivot point, and the cable is pulled to disengage the clutch. The quadrant spring keeps light tension on the cable, and when the clutch pedal is released, the pawl ratchets over the quadrant teeth and returns with the pedal to a stop on the pedal bracket.

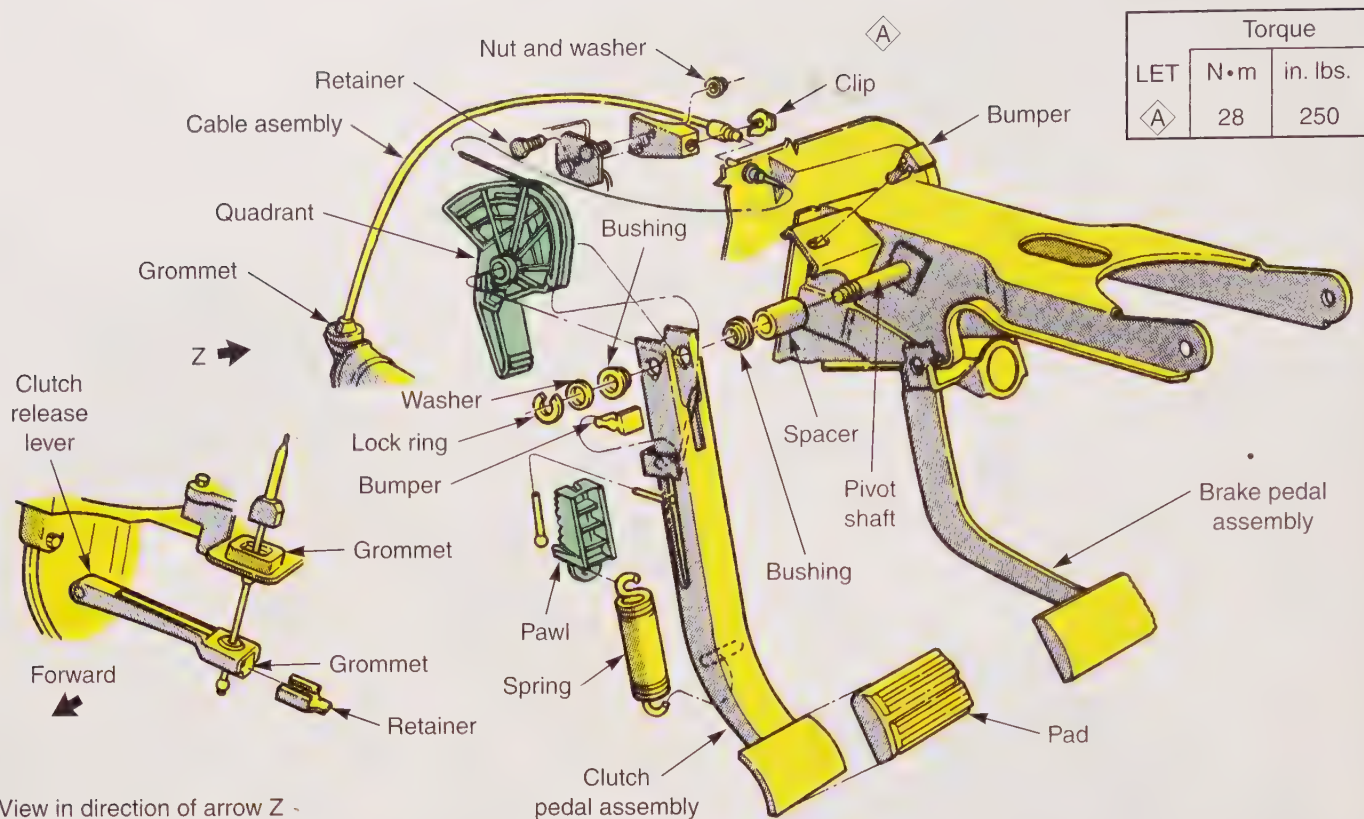
As the cable stretches from wear, the self-adjusting clutch picks up the slack. The quadrant automatically takes up the excess because of the quadrant spring. It causes the quadrant to pivot, keeping tension on the cable. Gradually, the quadrant pivots ahead. As it does, the pawl will engage successive teeth on the quadrant.

As the disc facing wears, the inner ends of the release levers or fingers gradually move away from the flywheel,

decreasing free play in the process. To compensate, more cable must be fed to the clutch fork to allow it to move further back. The movement of the release levers or fingers is translated to the quadrant. The quadrant adjusts its orientation when the pawl is free of the quadrant, which is when the pedal is in the upmost position. Thus, the quadrant makes adjustments by moving in either direction as cable or clutch wear dictates.

Hydraulic linkage uses hydraulic pressure to transfer pedal movement to the clutch fork. The system consists of a master cylinder and a slave cylinder connected by hydraulic lines. In addition, a fluid reservoir is connected to the master cylinder. The cylinders are made of cast iron or aluminum, and the pistons are aluminum. Steel tubing and high-pressure rubber hoses are used for the connecting lines.

The **master cylinder** is the controlling cylinder. It develops the system hydraulic pressure. The **slave cylinder** is the operating cylinder. It is actuated by the hydraulic pressure developed in the master cylinder. A typical system is illustrated in **Figure 6-22**.



View in direction of arrow Z -

Figure 6-20. The self-adjusting cable linkage consists of a quadrant and a pawl. The quadrant is mounted under the dash at the clutch pedal bracket. (Chrysler)

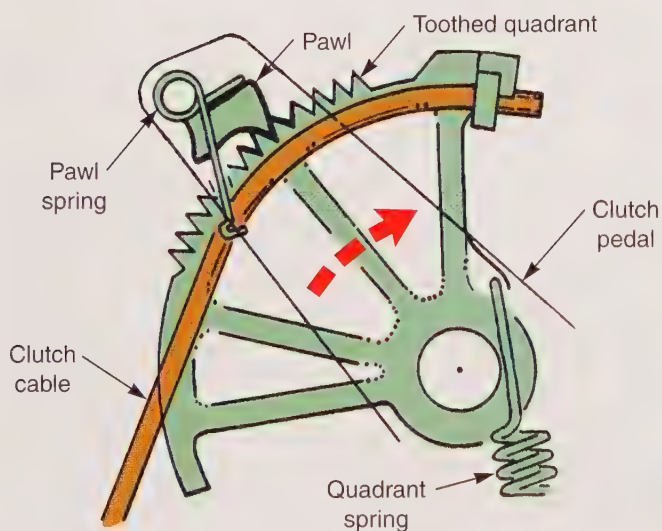


Figure 6-21. Note the action of a self-adjusting cable. The pawl engages teeth on the quadrant. When the clutch pedal is depressed, the pawl moves the quadrant, which pulls the cable. When the clutch is released, the pawl returns to its preset stop point. The cable is always held under tension. This is because any action that would cause it to lose tautness is automatically picked up by the quadrant. The pawl ratchets over the quadrant teeth, and the quadrant assumes its new position. (Ford)

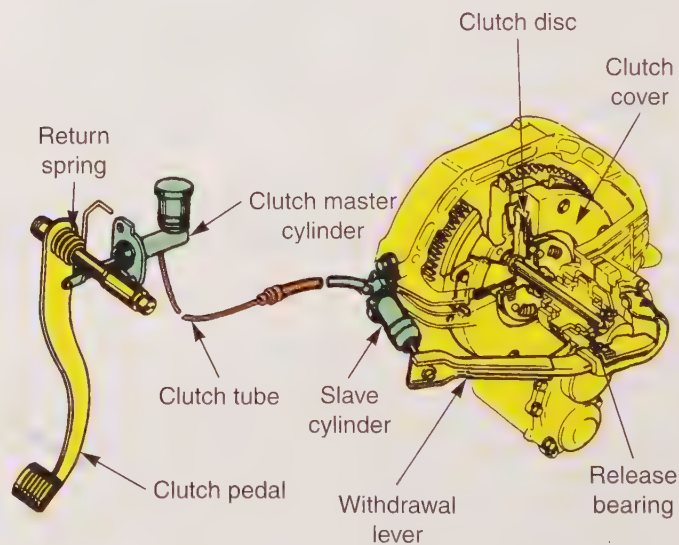


Figure 6-22. Hydraulic linkage is shown controlling the clutch of a manual transaxle. Pushing on the clutch pedal develops hydraulic pressure in the master cylinder. This pressure is transmitted through tubing to the slave cylinder. The slave cylinder piston moves out under pressure. This piston movement operates the clutch fork. Free play can be adjusted at the master cylinder or slave cylinder, depending on the particular system. (Subaru)

The master cylinder piston is actuated by a pushrod that is attached to the clutch pedal. Pushing on the pedal acts on the piston, creating hydraulic pressure. One end of the pushrod is retained within the master cylinder. The rod does not make contact with the piston, however, until the pedal is about 1" (25 mm) into its stroke.

The master cylinder is connected to the slave cylinder by hydraulic tubing. The slave cylinder piston is pushed outward by hydraulic pressure. The piston moves the clutch fork by means of a pushrod. See **Figure 6-23**. The clutch fork is returned, in many cases, by a return spring (not shown) that is attached to it.

The piston in the slave cylinder is sometimes larger than the piston in the master cylinder. The pressure developed in the master cylinder acts on a larger piston area in the slave cylinder. This increases the force the slave cylinder can apply to the clutch fork. In this way, the hydraulic linkage can multiply pedal force.

Two kinds of piston seals are used by the master and slave cylinders. These are often referred to as primary and secondary seals, or cups. The **primary seal** is used on the fluid end of the piston. Hydraulic pressure will force the

primary seal up against the cylinder wall, making for a tight seal. The seal, then, will keep fluid from leaking out so that the system can be pressurized. On the other hand, it will allow leakage when pedal pressure is released and the piston returns to its normal position. Some primary seals are lip seals. **Secondary seals** are used at the pushrod end of the piston. Their purpose is to keep system fluid from leaking out of the cylinder. Some secondary seals are ring seals.

Since the piston seals and hoses are made of natural rubber, **brake fluid** is used as the hydraulic fluid. **DOT 3** and **DOT 4** are the standards established by the Department of Transportation for modern brake fluids. Unlike petroleum-based products, these fluids will not damage rubber components. These standards also apply to brake fluid used in the clutch system. The exact type of brake fluid to be used is usually stamped on the reservoir cover.

The master cylinder contains a piston return spring. It also has a compensating port. See **Figure 6-24**. The spring speeds the piston's retraction. The compensating port allows fluid from the reservoir to enter the system.

The slave cylinder, **Figure 6-25**, is similar in design to the master cylinder; however, it contains no return spring, compensating port, or reservoir. Some slave cylinders do contain a spring, but the spring simply holds the cylinder primary seal in place. It does not function as a return spring.

In operation, when the clutch pedal is pushed and the piston is pushed forward in the cylinder, the compensating port is sealed off from the hydraulic system. As a result, fluid is trapped in the system and prevented from being pushed back into the reservoir.

When the clutch pedal is released, the piston return spring causes the piston to quickly retract. The master cylinder piston retracts more quickly than the slave cylinder piston. As a result, a low-pressure condition develops in

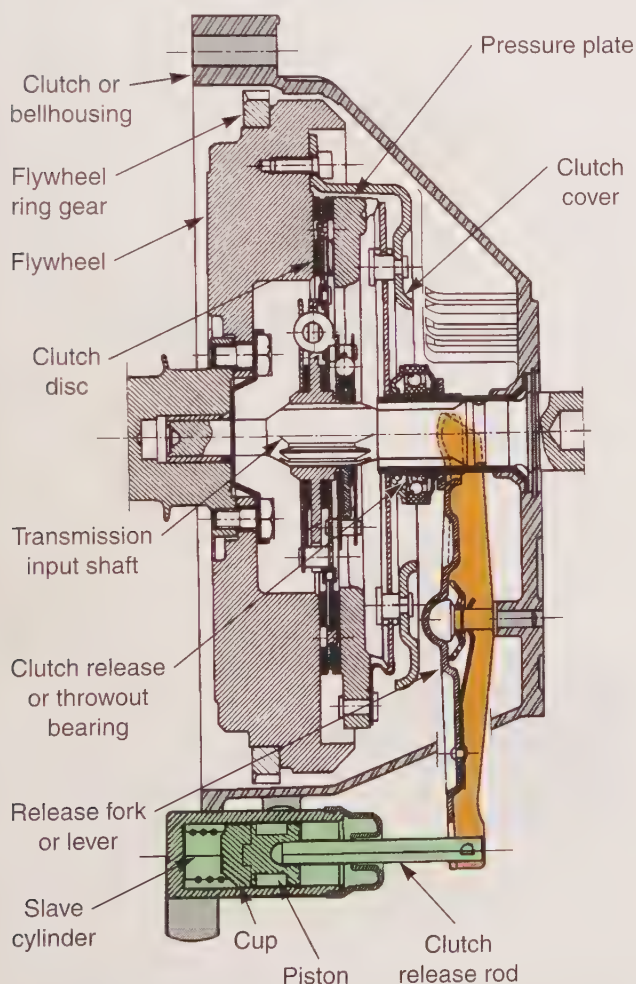


Figure 6-23. A slave cylinder is sometimes used for clutch fork operation. Hydraulic pressure moves the piston, which moves the pushrod. The pushrod moves the clutch fork. (Peugeot)

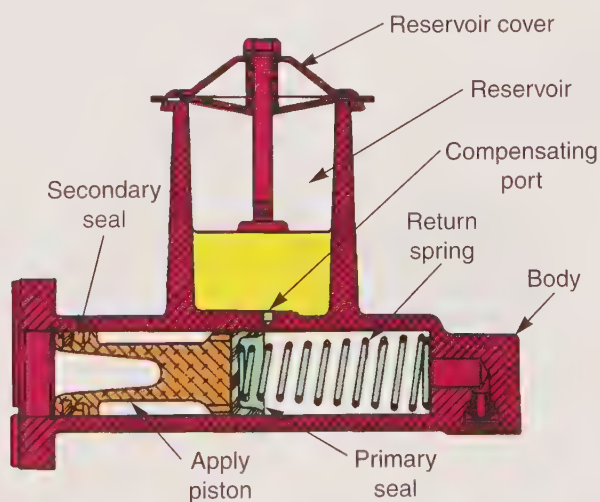


Figure 6-24. This sectional view of a clutch master cylinder shows the apply piston, return spring, and piston seals. Also shown is the fluid reservoir and compensating port.

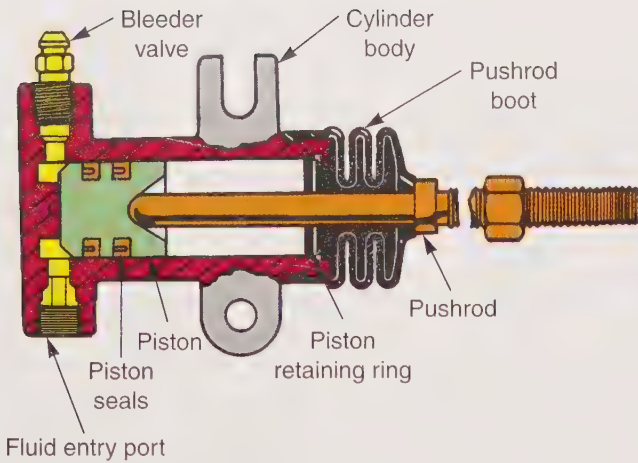


Figure 6-25. A typical slave cylinder contains a piston, pushrod, and seals. Some are equipped with a spring. The outer boot prevents entry of dirt or water. (General Motors)

the system. Hydraulic fluid will be pushed into the system by atmospheric pressure acting on the surface of the fluid in the reservoir. The fluid enters the system from the spooled region behind the primary seal. This region is supplied by the fluid reservoir via the compensating port. Due to the pressure differential, fluid leaks from behind the primary seal into the low-pressure zone. By this action, system pressure becomes equalized.

One variation of the hydraulic linkage uses a special design for the slave cylinder. In this variation, the slave cylinder and throwout bearing are combined into a single assembly, as shown in **Figure 6-26**. The cylinder and apply piston are ring-shaped. The entire assembly is installed over the shaft of the front bearing retainer. Hydraulic pressure from the master cylinder causes the ring-shaped piston to push directly on the throwout bearing. When this system is used, there is no clutch fork. The basic layout of this system is shown in **Figure 6-27**.

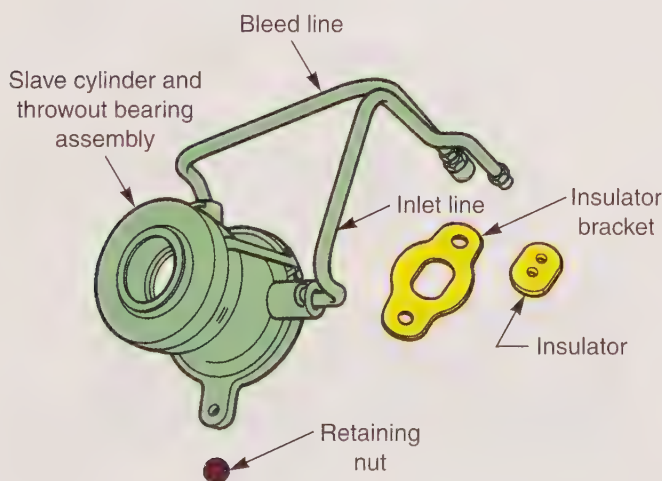


Figure 6-26. This type of slave cylinder is combined with the throwout bearing into a single assembly. There is no clutch fork. Some manufacturers call this design an annular slave cylinder. (Chrysler)

Clutch Housing

The clutch housing, or **bellhousing**, is bolted to the engine. It supports the transmission or transaxle and encloses the clutch. In some designs, the transmission is bolted to the clutch housing. In other designs, the two are combined as a one-piece, or integral, casting. Almost all transaxles are of the latter type. When properly installed, the clutch housing holds the centerlines of the engine crankshaft and transmission input shaft in alignment. The integral design reduces the chance of misalignment between engine and transmission.

Most clutch housings are light aluminum castings; however, some housings used on trucks and older cars are made from cast iron. A sheet metal clutch access cover is found on the front of the clutch housing. The cover can be removed for inspection purposes or for clutch repairs.

The clutch housing prevents the entry of dirt, oil, or moisture into the clutch assembly. An opening in the housing, which is used for the clutch fork, is usually sealed by a rubber boot. Most clutch housings have a series of

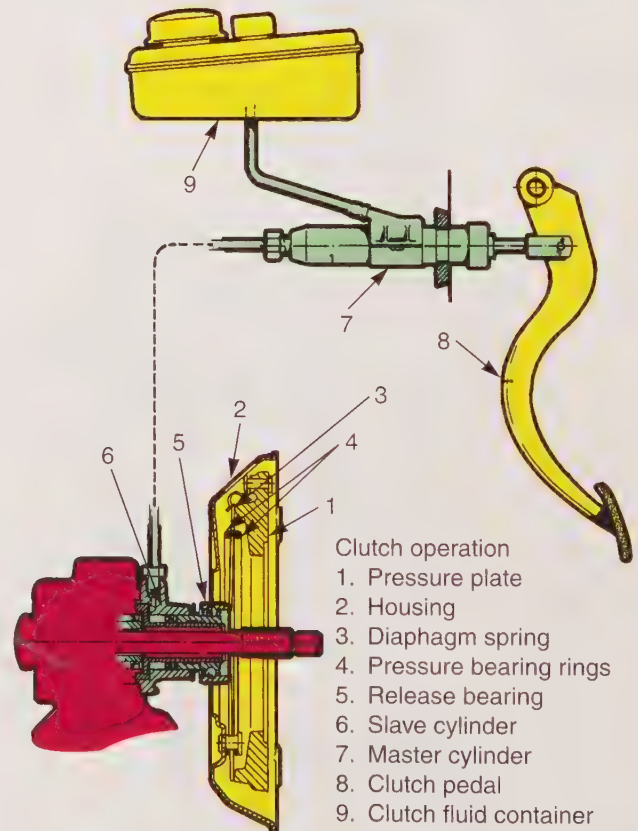


Figure 6-27. Study the action of the slave cylinder when mounted with the throwout bearing. Hydraulic pressure moves the slave cylinder piston outward. The piston pushes directly on the throwout bearing, moving it into contact with the pressure plate release levers or fingers. (Saab)

slots, which permits air circulation within the housing. This aids in removal of heat generated by the clutch. Clutch housings have an opening at the bottom so that any oil or water that gets inside can drip out.

On many vehicles, the starter motor, or starter, is attached to the clutch housing. Inside the clutch housing, the starter drive pinion engages the flywheel ring gear to crank the engine. The housing and starter must be carefully aligned to prevent damage to the starter drive pinion and to the flywheel ring gear. In addition, a heavier steel access cover must be used. It adds strength, which is needed to handle the severe forces put on the clutch housing as the starter cranks the engine. This type of access cover is often called a stiffener plate.

Summary

The clutch is a device for engaging and disengaging the engine from the rest of the drive train. It is used on every vehicle that has a manual transmission. The clutch allows the engine to operate when the vehicle is not moving. The clutch is also used to disengage the engine and transmission when shifting gears.

The single-plate dry clutch consists of eight major components. The basic action of the clutch assembly consists of pressing a friction disc between a flywheel and pressure plate. When the disc is pressed between the other two parts, all three rotate as a single unit. Power is then transmitted from the engine to the transmission. When the disc is not pressed between the flywheel and pressure plate, power is not transmitted.

The transmission input shaft is mounted on bearings or bushings at each end. The front end of the input shaft extends into the rear of the engine crankshaft. The rear end of the input shaft contains the transmission input gear. The input shaft is splined to the clutch friction disc and transfers engine power into the transmission.

The clutch disc is made of a heat-resistant composite material. The disc assembly contains springs that cushion the shock of engagement. The clutch disc is splined to the input shaft. The splines allow the disc to move slightly as it is engaged and disengaged.

The pressure plate assembly consists of three major parts. The cover bolts to the flywheel and contains the other parts. The pressure plate provides the contact surface with the friction disc. The springs press the friction disc between flywheel and pressure plate.

There are two kinds of springs used on modern pressure plate assemblies. The diaphragm type is a single dish spring, which flexes to apply and release the clutch. Other pressure plate assemblies use multiple coil springs to provide pressure.

The throwout bearing operates the pressure plate release levers or fingers. The throwout bearing slides on a hub built as part of the input shaft bearing retainer. The throwout bearing consists of a ball bearing assembly mounted on a collar. The ball bearing allows the throwout

bearing assembly to contact the spinning release levers without damage.

The clutch fork operates the throwout bearing. The clutch fork is a simple lever device that reverses and increases the clutch pedal force. The fork pivots on a ball stud inside of the clutch housing. Some clutch forks are mounted on a shaft, which turns to move the fork.

The clutch linkage allows the driver to operate the clutch mechanism easily. All linkages multiply pedal force. In the process, the distance traveled by the pedal is reduced to a much smaller distance traveled by the throwout bearing.

The rod-and-lever linkage consists of a set of pushrods and levers that transmit clutch pedal pressure to the clutch fork. Pressure delivered at the throwout bearing depends on the placement of the rods and levers. The linkage can usually be adjusted at the clutch fork.

The cable linkage uses a cable in place of pushrods and levers. Pushing the clutch pedal pulls the cable, which pulls the clutch fork. This type of linkage can also be adjusted. Some cable linkages have a self-adjusting feature.

The hydraulic linkage uses hydraulic pressure to transfer pedal pressure to the clutch fork. Pressure developed in the clutch master cylinder is transferred to the slave cylinder, which operates the clutch fork. One type of slave cylinder is built into the throwout bearing assembly, and a clutch fork is not needed.

The clutch itself is enclosed in a clutch housing. This housing protects the clutch parts from dirt, water, and oil.

Review Questions—Chapter 6

Answer the following questions using the information provided in this chapter.

1. What is the function of a clutch?
2. List the eight basic parts of a clutch, and tell what role each part serves in clutch operation.
3. The raised ring on the crankshaft flange fits into a hole in the center of the ____.
4. What is the purpose of the pilot bearing?
5. Which part transmits power from the engine flywheel to the transmission input shaft?
 - (A) Pressure plate.
 - (B) Throwout bearing.
 - (C) Clutch disc.
 - (D) Clutch fork.
6. How does the pressure plate assembly work?
7. Briefly describe the two types of clutch forks and their operation.
8. The distance the clutch pedal will travel before resistance is felt by the driver is called ____.
9. Briefly describe the three types of clutch linkages.
10. How does a self-adjusting clutch work?

ASE-Type Questions—Chapter 6

1. The main purpose of the clutch is to _____.
 - (A) absorb heat
 - (B) dampen engine vibration
 - (C) transfer engine power into the transmission
 - (D) connect or disconnect power flow from engine to road
2. Each of the following is a function of the flywheel *except*:
 - (A) transferring engine power to the clutch.
 - (B) providing a mounting surface for parts of the clutch.
 - (C) holding the input shaft in proper alignment.
 - (D) serving as a vibration damper.
3. The clutch linkage is designed to _____.
 - (A) slide the throwout bearing into the pressure plate assembly
 - (B) hold the clutch disc against the flywheel
 - (C) allow the driver to operate the clutch fork
 - (D) transfer power flow from the clutch to the transmission
4. Each of the following is turning when the engine is running and the clutch is engaged *except*:
 - (A) the flywheel.
 - (B) the clutch disc.
 - (C) the clutch fork.
 - (D) the input shaft.
5. Technician A says that the flywheel is generally made of cast iron. Technician B says that a hardened-steel ring is usually mounted on the outside of the flywheel. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
6. The manual transmission input shaft _____.
 - (A) is made of aluminum
 - (B) holds the flywheel in alignment with the clutch components
 - (C) extends from the transmission case to the drive shaft
 - (D) transmits motion from the clutch disc to the transmission
7. Technician A says that the clutch disc is located between the flywheel and the pressure plate. Technician B says that the clutch disc transfers power from the engine crankshaft to the flywheel. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
8. Under their friction facings, most friction discs contain _____.
 - (A) hub springs
 - (B) torsion springs
 - (C) cushion springs
 - (D) apply springs
9. For engine power to get from the clutch disc to the hub flange, it must actually go through which of these springs?
 - (A) Apply springs.
 - (B) Torsion springs.
 - (C) Cushion springs.
 - (D) Diaphragm springs.
10. Each of the following is a part of the pressure plate assembly *except*:
 - (A) the clutch cover.
 - (B) apply springs.
 - (C) the throwout bearing.
 - (D) a pressure plate.
11. Technician A says that slots in the clutch cover aid in heat dissipation. Technician B says that the openings allow air to circulate inside of the assembly. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
12. The pressure plate is a ring-shaped disc that is made of _____.
 - (A) cast iron
 - (B) aluminum
 - (C) high-strength steel
 - (D) plastic

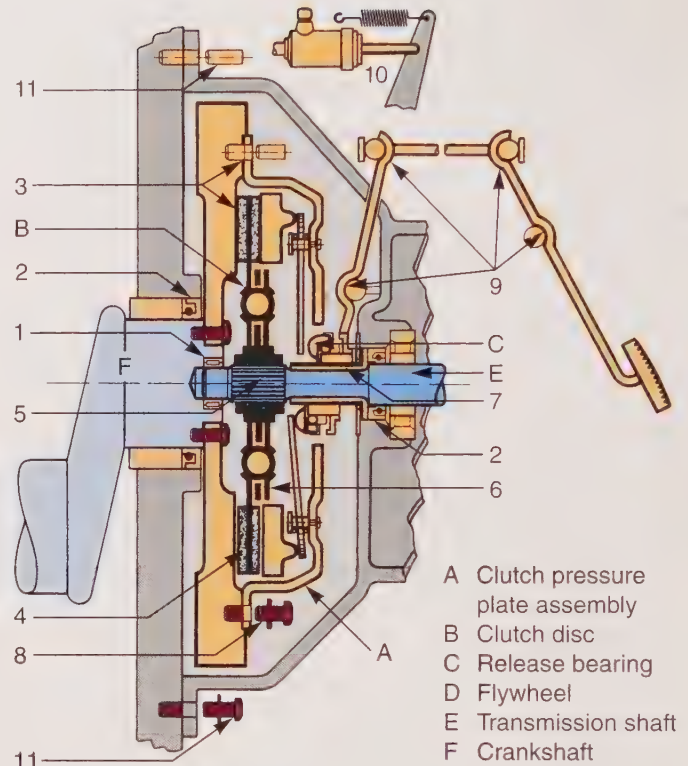
13. Which of the following is built into the pressure plate assembly near the outer rim?
 - (A) Pivot rings.
 - (B) Clutch rings.
 - (C) Primary rings.
 - (D) Pressure rings.
14. In a coil-spring pressure plate assembly, springs are pressed between the plate and the cover. Technician A says that four springs must be used. Technician B says that at least ten are needed. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
15. Release levers are used in _____.
 - (A) throwout bearing assemblies
 - (B) coil-spring pressure plate assemblies
 - (C) outer clutch disc assemblies
 - (D) clutch fork assemblies
16. Each of the following is a part of a throwout bearing assembly *except*:
 - (A) a collar.
 - (B) a sleeve.
 - (C) a thrust bearing.
 - (D) rod-and-lever linkage.
17. Technician A says that the throwout bearing must be greased occasionally to ensure proper operation. Technician B says that the throwout bearing is generally lubricated at the factory and cannot be greased without removing the transmission. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
18. The function of the release fork is to _____.
 - (A) pull the throwout bearing away from the release levers
 - (B) connect the clutch linkage to the throwout bearing
 - (C) slide on the hub of the front bearing retainer
 - (D) rotate on the retainer hub to absorb spinning pressure shock
19. Technician A says that the clutch fork components are made of hardened steel. Technician B says that the clutch fork transfers the force of the clutch pedal and linkage to the throwout bearing. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
20. Which of the following is used to overcome apply spring pressure and disengage the clutch?
 - (A) Clutch pedal.
 - (B) Free play.
 - (C) Gearshift lever.
 - (D) Return spring.
21. Technician A says that pedal reserve is the distance that the pedal will travel before the slack in the linkage is taken up and any resistance is felt by the driver. Technician B says that free play is the amount that the pedal can be depressed beyond the point at which the clutch is fully disengaged. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
22. Each of the following is a type of clutch linkage *except*:
 - (A) pedal linkage.
 - (B) cable linkage.
 - (C) hydraulic linkage.
 - (D) rod-and-lever linkage.
23. Technician A says that all clutch linkages must have some provision for adjustment. Technician B says that the throwout bearing must be moved closer to the release levers as parts wear. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
24. Each of the following is a part of a hydraulic clutch linkage *except*:
 - (A) master cylinder.
 - (B) fluid reservoir.
 - (C) slave cylinder.
 - (D) pawl and quadrant assembly.
25. Which of the following engages the flywheel ring gear to crank the engine inside the clutch housing?
 - (A) Clutch fork.
 - (B) Release lever.
 - (C) Starter motor.
 - (D) Starter drive pinion.

First things first:

- Make sure you have the right parts.
- Compare disassembled parts with new parts before you install them.

Pay special attention:

1. Always replace the pilot bearing or bushing when in doubt.
2. Check engine and transmission shaft seals. Any leaks are going to ruin the new disc.
3. Examine flywheel and pressure plate contact surfaces for scoring and nicks. Regrind the flywheel friction surface if necessary.
4. Maximum clutch disc axial runout should be 0.5 mm (0.02 in.).
5. Ensure that the clutch disc travels easily along the transmission shaft. Remove residue. Grease spline (small amount of long life grease). Insert shaft horizontally. Do not damage spline. Use only correct alignment tools.
6. Make certain that the side of the disc marked "flywheel side" is toward the flywheel.
7. Check release bearing collar and ensure that it runs easily. If worn down, replace. Grease sliding surface with small amount of long-life grease.
8. Tighten clutch cover mounting bolts no more than two turns at a time, alternating back and forth from one side of the assembly to the other.
9. Check clutch linkage system for wear, proper function, and adequate lubrication. Is the clutch easy to operate?
10. In the case of hydraulic release systems, check the slave cylinder. Bleed the system and change the hydraulic fluid.
11. Check correct centering between the clutch housing and the engine.



Suggestions for problem-free clutch replacement. Note drawing shows both engaged and disengaged positions of throwout bearing and release levers. (Luk)



Chapter 7

Clutch Problems, Troubleshooting, and Service

After studying this chapter, you will be able to:

- ☐ Describe the common problems that can occur in a clutch assembly.
- ☐ Adjust a clutch.
- ☐ Remove a clutch assembly.
- ☐ Inspect clutch parts for wear and damage.
- ☐ Remove and replace a flywheel and a pilot bearing.
- ☐ Disassemble, repair, and install various clutch parts.
- ☐ Install a clutch assembly.

Technical Terms

Riding the clutch	In-car service
Dumping the clutch	Clutch adjustment
Clutch drag	Constant-duty throwout bearing
Clutch slippage	Bleeder valve
Grabbing clutch	Radial runout
Clutch chatter	Lateral runout
Clutch vibration	

Introduction

This chapter explains how to diagnose and service clutches. Clutch problems and their causes are identified. Procedures performed with the clutch in place, such as clutch adjustment, are covered. Major repair and replacement procedures, which require clutch removal, are also explained.

Clutch Problems and Troubleshooting

You cannot properly service a clutch until you know what is wrong with it. In many instances, a clutch problem that seems to be severe is minor and easily remedied. In other cases, the solution involves replacing

the clutch assembly or some other major component. Check the easiest, most obvious solutions (such as clutch adjustment) before removing the clutch. Also, look beyond the clutch for possible solutions. Consider the possibility the problem is something other than the clutch. **Figure 7-1** shows typical clutch problems. Study them carefully.

Clutch discs are like brake linings: they gradually wear out as they operate. Every time the clutch is engaged or disengaged, some friction material is removed from the clutch disc. The amount of material lost during each action is small, and most clutches will last for 50,000 miles (80,000 km) or more. It is normal for a clutch to wear out after this mileage is reached.

Often, however, a clutch will not last as long as 50,000 miles. Like any other mechanical part, the clutch can be damaged by careless or abusive operation. Further, it can be damaged by outside factors—factors that cannot be attributed to the vehicle operator. It is important for

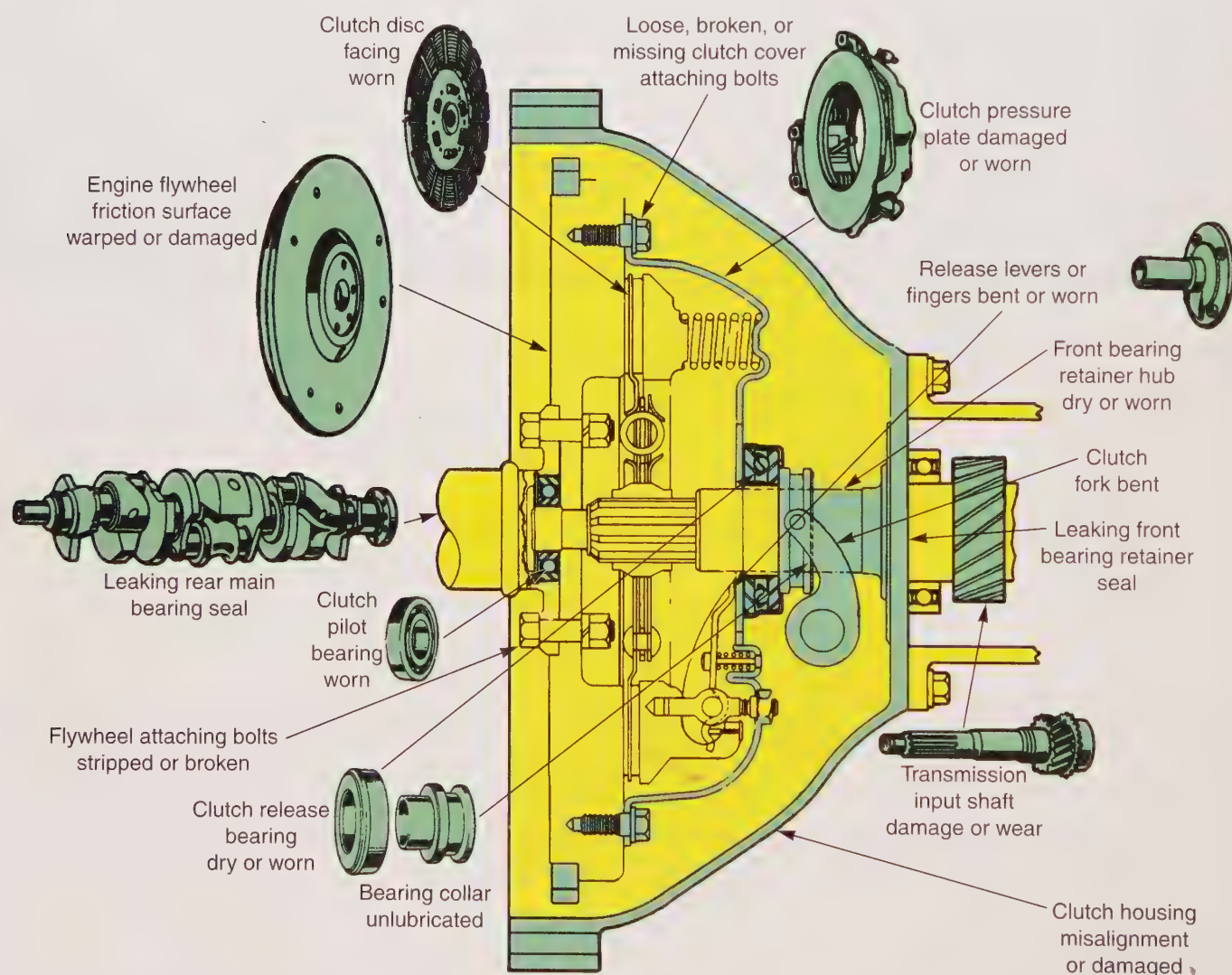


Figure 7-1. Note typical problems with the clutch assembly. Some defective parts, such as a leaking engine oil seal, are not part of the clutch assembly but can cause clutch problems. It is very unusual for only one part of a clutch to wear out. You should usually replace any clutch part that you suspect is bad. (Chrysler)

you, the technician, to find out what caused the premature clutch damage, so the problem might be prevented in the future.

As stated, clutch problems can occur as a result of careless operation. Driving with a foot resting on the clutch pedal is an example. This careless habit, called **riding the clutch**, causes the clutch to slip. As a result, excess heat is generated and premature wearing of clutch friction surfaces occurs. Among the different ways clutches are misused, riding the clutch is the most common. It can put the equivalent of 50,000 miles of normal wear on a clutch in under 10,000 miles.

Naturally, clutch problems can occur as a result of abuse. An example is increasing engine speed and then suddenly releasing the clutch pedal, allowing the pressure plate apply springs to engage the clutch almost instantly. This is often referred to as **dumping the clutch**, or **popping the clutch**. It causes instant heat buildup in the clutch disc facings and places tremendous stress on the clutch and the entire drive train.

Clutches usually do not last very long under this type of abuse. Overheated clutch facings, a result of dumping the clutch, can become glazed within seconds. This form of abuse can also cause flywheel, clutch cover, or clutch housing attaching bolts to shear off. Further, it can cause clutch disc hub splines to be stripped or input shafts to break.

Placing more load on a clutch than it is designed to handle can also be a source of damage. An example is starting off in high, rather than in low, gear. Shifting into a higher gear before the engine has reached the proper rpm also overloads the clutch, as does attempting to change gears at very high engine speeds. Another example is overloading the vehicle to the point that the clutch must be allowed to slip heavily when starting off, just to get the vehicle moving. This is a common problem on vehicles used for towing.

As stated, outside factors can also cause clutch damage. Oil leaks from the engine rear main bearing seal or from the transmission front bearing retainer seal can reach the clutch disc. If the disc gets contaminated with oil, it grabs or chatters when engaged. If enough oil gets on the disc, it slips at all times and the disc surfaces soon wear out from the resulting friction. If the disc becomes completely saturated with oil, the surface does not wear out, but the disc itself becomes useless.

Finally, many clutch problems are due to lack of maintenance or careless service. If the clutch linkage is not adjusted and lubricated on schedule, or if the throwout bearing or clutch hub splines are not properly greased during installation, the moving parts may hang up or operate slowly. The clutch is subjected to undesirable slippage, shortening its life. Slippage and other problems exhibited in clutch operation are presented in detail in the upcoming paragraphs. **Figure 7-2** summarizes some common conditions and their causes and corrections.

Clutch Drag

If the clutch cannot be disengaged or it fails to release, you cannot shift gears. In this situation, when you stop the vehicle in gear (clutch pedal depressed), the engine stalls. This condition is known as **clutch drag**.

Clutch drag varies in degree. Slight drag when the clutch pedal is fully depressed may tend to make the car creep when in gear or cause gear clash when the gears are first engaged. The two most common causes of slight drag are improper linkage adjustment and lack of lubrication at the moving parts of the linkage.

In some cases, the car creeps during the clutch spindown, wherein the disc continues to spin for several seconds after being disengaged. To determine if this is causing the creeping and not clutch drag, a simple test can be performed (if the transmission is not fully synchronized). Depress the clutch pedal, shift into Neutral, and wait about 30 seconds. Then, shift into an unsynchronized gear, usually reverse. If the gear engages smoothly, the creeping is caused by spindown, which is normal. If the gear clashes, the creeping is caused by clutch drag. (Consult Chapter 8 for an explanation on synchronizers.)

Clutch drag can be caused by a clutch linkage that is loose, disconnected, or inoperable. The clutch fork inside the clutch housing may be disconnected from the throwout bearing. A hydraulic linkage may be low on fluid—the reservoir may be empty, or the cylinders or lines may be leaking. There might be air in the system. A disconnected linkage or clutch fork or a dry hydraulic system is characterized by a pedal that requires little, if any, effort to depress. A spongy pedal is the result of air in a hydraulic linkage.

Another possible cause of clutch drag is misalignment of the transmission or clutch housing. This can happen as a result of loose bolts or as a result of debris between the mounting faces. Misalignment can cause the linkage or internal clutch parts to stick temporarily. Pedal effort will be normal or higher than normal.

Clutch drag can also be caused by a worn or frozen pilot bearing, a sticking or warped clutch disc, or a warped pressure plate or flywheel. A worn disc may become so overheated, it welds itself to the pressure plate. When these defects occur, the clutch linkage is working properly but the engine and transmission remain mechanically connected.

One of the most common causes of a dragging clutch is too much pedal free travel. With excessive free travel, the pressure plate may back off somewhat, but it will still retain contact with the disc when the pedal is pushed to the floor. Always check the clutch linkage adjustment when indications point to a dragging clutch.

Clutch Slippage

Clutch slippage is a condition wherein the full power of the engine does not reach the transmission. The engine

Clutch Trouble Diagnosis

Condition	Probable Cause	Correction
Fails to Release (Pedal pressed to floor. Shift lever does not move freely in and out of reverse gear.)	a. Improper linkage adjustment. b. Improper pedal travel. c. Loose linkage. d. Faulty pilot bearing. e. Faulty driven disc. f. Fork off ball stud. g. Clutch disc hub binding on clutch gear spline. h. Clutch disc warped or bent. i. Loose pivot rings in cover assembly.	a. Adjust linkage. b. Trim bumper stop and adjust linkage. c. Replace as necessary. d. Replace bearing. e. Replace disc. f. Install fork onto stud. Lightly lubricate fingers at release bearing. Also lube bearing I.D. groove. g. Repair or replace clutch gear and/or disc. h. Replace disc (runout should not exceed 0.020"). i. Replace plate and cover assembly.
Slipping	a. Improve adjustment (no lash). b. Oil soaked driven disc. c. Worn facing or facing torn from disc. d. Warped pressure plate or flywheel. e. Weak diaphragm spring. f. Driven plate not seated in. g. Driven plate overheated.	a. Adjust linkage to spec. b. Install new disc and correct leak at its source. c. Replace disc. d. Replace pressure plate or flywheel. e. Replace pressure plate. (Be sure lash is checked before replacing plate.) f. Make 30 to 40 normal starts. CAUTION: Do Not Overheat. g. Allow to cool—check lash.
Grabbing or Chattering	a. Oil on facing. Burned or glazed facings. b. Worn splines on clutch gear. c. Loose engine mountings. d. Warped pressure plate or flywheel. e. Burned or smeared resin on flywheel or pressure plate.	a. Install new disc and correct leak. b. Replace transmission clutch gear. c. Tighten or replace mountings. d. Replace pressure plate or flywheel. e. Sand off if superficial, replace burned or heat checked parts.
Rattling-Transmission Click	a. Weak retracting springs. b. Release fork loose on ball stud or in bearing groove. c. Oil in driven plate damper. d. Driven plate damper spring failure.	a. Replace pressure plate. b. Check ball stud and retainer. c. Replace driven disc. d. Replace driven disc.
Throwout Bearing Noise with Clutch Fully Engaged	a. Improper adjustment. No lash. b. Release bearing binding on transmission bearing retainer. c. Insufficient tension between clutch fork spring and ball stud. d. Fork improperly installed. e. Weak linkage return spring.	a. Adjust linkage. b. Clean, relubricate, check for burrs, nicks, etc. c. Replace fork. d. Install properly. e. Replace spring.
Noisy	a. Worn release bearing. b. Fork off ball stud (heavy clicking). c. Pilot bearing loose in crankshaft.	a. Replace bearing. b. Install properly and lubricate fork fingers at bearing. c. See Section 6 for bearing fits.
Pedal Stays on Floor When Released	a. Bind in linkage or release bearing. b. Springs weak in pressure plate. c. Springs being over traveled.	a. Lubricate and free up linkage and release bearing. b. Replace pressure plate. c. Adjust linkage to get proper lash, be sure proper pedal stop (bumper) is installed.
Hard Pedal Effort	a. Bind in linkage. b. Driven plate worn.	a. Lubricate and free linkage. b. Replace driven plate.

Figure 7-2. Clutch diagnosis chart. (General Motors)

speeds up, but the vehicle speed does not increase as it should. The clutch disc is not being gripped firmly, and it slips between the flywheel and pressure plate as the members rotate.



Note: In this section, we are referring to abnormal clutch slippage. For smooth shifts, some degree of slippage is desirable.

The clutch pedal should not be released too quickly. A controlled release will permit some slippage. As a result, you will not ruin the clutch or other parts of the drive train. In addition, it makes the ride easier on the vehicle occupants.

Clutch slippage begins as a minor problem. At first, it will occur on initial and hard accelerations. As the problem progresses, slippage will occur on upshifts, downshifts, and on any kind of acceleration. Left uncorrected, slippage only becomes worse. Eventually, the clutch disc becomes so badly worn that there is not enough friction present to move the vehicle.

A slipping clutch gets very hot. The extreme heat damages the contact surfaces of the pressure plate and flywheel, causing them to lose their proper finish. This happens because the heat changes the chemical makeup of the metal, reducing its strength and heat absorption capability. A slipping clutch should be repaired before the pressure plate or flywheel is damaged by excessive heat.

A badly slipping clutch is usually too glazed and worn down to be fixed by adjustment. A clutch disc that is too glazed cannot develop any driving friction between itself and the flywheel and pressure plate. If the clutch disc is completely worn down, the apply springs will not be able to apply enough pressure to the pressure plate to hold it tight against the flywheel. The clutch must be replaced.

A clutch disc that is soaked with oil, such as from a leaking rear main bearing seal, will also slip. In this case, the clutch may not be worn down. If the clutch disc is soaked with oil, however, it must be replaced.

A clutch often slips if the vehicle is driven through deep water. This is because water enters the clutch housing and soaks the clutch disc. The clutch will usually work normally after the disc dries.

Slippage can also be caused by disc, pressure plate, or flywheel contact surfaces that are warped. If the surface is not perfectly flat and straight, the flywheel or pressure plate will not make good contact with the disc. As a result, the disc may slip (or chatter). Warped surfaces may be caused by improper manufacturing processes or by excessive heat.

Sometimes, a clutch slips because the pressure plate apply springs are weak. Weak springs may have been installed in the pressure plate assembly originally, or the assembly may have been intended for a smaller engine or vehicle. The springs may have become weak from overheating, or under normal circumstances, the springs may have become weak because of long usage. A clutch pedal

that depresses with almost no effort may be a sign of weak clutch apply springs.

Clutch slippage can be caused by improper clutch linkage adjustment. If the clutch linkage is adjusted to where there is no free play and the throwout bearing is applying pressure to the release levers or fingers, the clutch will not be fully applied, and it will slip.

Note that if the clutch fork return spring is disconnected, the pedal will have no free play. However, this condition will not cause slippage. When the clutch pedal is released after being applied, the apply springs will fully re-engage the clutch. The throwout bearing will ride on the release levers or fingers but will not apply pressure on them to cause slippage. Therefore, do not confuse this condition with the lack of free play caused by misadjustment.

Grabbing Clutch

A **grabbing clutch** engages with a jerk or shudder no matter how slowly and carefully it is applied. The effect may be a series of jerks, which is often described as bucking. This problem may be severe enough to cause damage to universal joints or other drive train parts.

If you suspect a grabbing clutch, always check the engine and transmission or transaxle mounts before troubleshooting the clutch. Loose mounts can cause a sensation similar to a grabbing clutch. Also, make sure all clutch housing and transmission bolts are tight.

A grabbing clutch is usually caused by oil deposits disbursed on the friction facing of the clutch disc or by an overly hot or glazed facing. Less common causes are worn splines on the clutch disc hub flange or transmission input shaft, a warped clutch disc, or warped pressure plate or flywheel machined surfaces. Another possible cause is a worn or misaligned clutch fork. This can cause the release bearing to become crooked or tip on its shaft. The result is an uneven application of pressure on the pressure plate assembly. The bearing collar may begin to wear because of the uneven pressure from the fork.

Clutch Chatter

Clutch chatter is a specific type of vibration that is accompanied by a rapid clunking or rattling noise. It occurs while the clutch is being engaged, as opposed to while the clutch is fully engaged. It is closely related to clutch grabbing. It differs, however, in that it is heard more than it is felt. The actual noise is caused not by the clutch, but by the vibration set up in the clutch linkage and drive train. Chatter can be caused by loose or misaligned drive train components. For example, the transmission and clutch housing may be seriously misaligned.

Often, what seems like clutch chatter is really a worn out constant-velocity joint or other universal joint. Other causes of chatter include a misaligned flywheel, a worn pilot bearing, or both. It is possible that release levers are unevenly adjusted or worn. Sometimes, dust from a worn clutch disc facing clogs the disc segments and cause chatter.

Clutch Vibration

Some clutch defects can result in a vibration that can be felt inside of the vehicle while the clutch is fully engaged. This **clutch vibration** varies with engine speed. It differs from chatter, which occurs when the clutch is in the process of being engaged or disengaged. Often, clutch vibration is accompanied by noise; however, the noise is a secondary symptom.

Several checks must be made to find the source of the vibration. This is to determine if the problem is clutch vibration or vibration from another source.

Vibration with the vehicle moving may be caused by the engine or any part of the drive train. To narrow down the possibilities, determine when the problem occurs. If the vibration occurs only when the vehicle is moving, the problem is probably not clutch related. Even so, you should check the bolts that secure the clutch housing to the engine and to the transmission just to make sure they are not loose. Thoroughly check the drive shaft assembly, drive axles, and engine mounts. Closely inspect conventional or constant-velocity joints for any signs of wear. In rare cases, internal problems in the transmission or differential or the transaxle may cause vibration while the vehicle is moving. (Refer to later chapters related to these components.)

If the vibration also occurs with the vehicle stopped (transmission in Neutral), the source of the problem is related to the clutch or the engine. Check the engine for a dead cylinder or other internal problem. Vibration resulting from excessive crankshaft endplay can be identified by disengaging the clutch. Pressure from the throwout bearing will push the flywheel and crankshaft forward, taking up the endplay and eliminating any corresponding vibration.

If the engine is okay, look for problems indirectly related to the clutch. First, however, check the clutch housing where it attaches to the engine and to the transmission. Check the front bearing retainer where it attaches to the transmission. Ensure all bolts are tight, **Figure 7-3**. Look at the transmission front bearing as a possible cause of vibration.

Inspect the clutch assembly if the previously mentioned checkpoints have failed to identify the source of vibration. There are two general sources of clutch vibration:

- ❑ A part associated with the clutch assembly is out of balance. The parts that are heavy enough to be seriously unbalanced are the flywheel and pressure plate. A balance problem is often found after new parts are installed or the flywheel is resurfaced. The chance of a flywheel or pressure plate becoming seriously unbalanced after long use is slight.
- ❑ A part associated with the clutch assembly is loose or broken. Check attaching bolts of the clutch assembly. The flywheel attaching bolts (flywheel-to-crankshaft bolts) may be loose on the crankshaft, or there may be dirt or metal burrs between the crankshaft flange and flywheel. This causes misalignment of the flywheel. When this happens, the clutch usually has other symptoms. The clutch may slip or make a knocking noise.

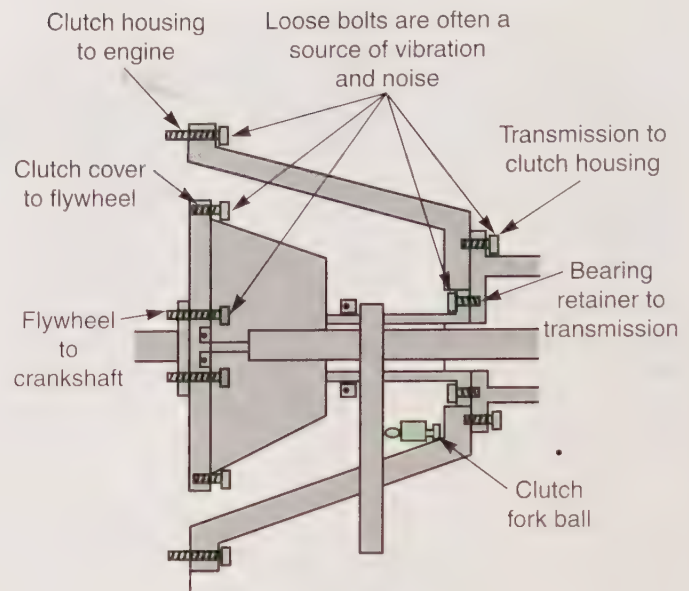


Figure 7-3. Note places where bolts can loosen, causing vibration (and noise). Often, bolts can be tightened to solve the problem. Occasionally, the vibration will damage other parts before the bolts are tightened.

Clutch Explosion

A clutch explosion occurs when clutch components fly apart due to centrifugal force. Major causes of clutch explosions are excessive clutch rpm, severely unbalanced components, and loose pressure plate fasteners. A clutch explosion destroys all clutch components and often breaks the clutch housing. A clutch used for racing will often have a scatter shield installed over the clutch housing. This keeps flying clutch components from entering the passenger compartment.

Abnormal Noise

Often, the clutch is blamed for a noise when some other component is at fault. Any vehicle component can become noisy under the right conditions. An abnormal noise in the clutch can usually be singled out by applying or releasing the clutch pedal. If the clutch is the source of the noise, this will have some effect on the noise being made.

Rumbling, squealing, whirring, or grinding noises can be caused by a defective transmission front bearing, throwout bearing, or pilot bearing. A defective transmission front bearing will commonly make noise as the clutch drives the input shaft, whenever the clutch is engaged. A defective throwout bearing makes noise as the bearing is applied. A noisy pilot bearing is usually heard when the clutch is disengaged completely. It will not usually make noise when the clutch is engaged, since the crankshaft and input shaft are turning at the same speed, **Figure 7-4**.

Follow these procedures to isolate defective bearings:

1. While depressing the clutch pedal, start the engine and leave it running. With the transmission in Neutral, release the clutch pedal, taking your foot completely off the pedal. Any noise that you hear upon engaging the clutch will likely be coming from the transmission front bearing.

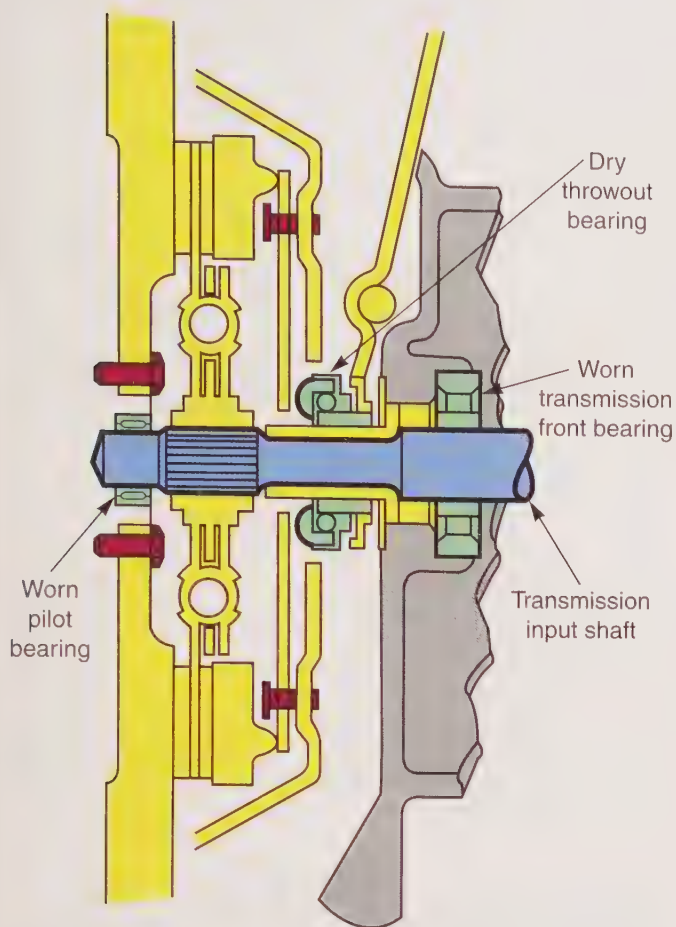


Figure 7-4. Three bearings associated with the clutch are the pilot bearing, the throwout bearing, and the transmission front bearing. Each can be detected as a source of noise by operating the clutch pedal. Wear or lack of lubrication can cause the bearings to make noise. (Luk)

2. Push the clutch pedal *only* until all free play is removed. This causes contact with the release levers or fingers, allowing the throwout bearing to rotate without disengaging the clutch. If you hear a noise in this position, typically a whirring or grinding sound, the throwout bearing is probably defective.
3. Push the clutch pedal to the floor. If a noise—typically, a squealing or howling sound—occurs on disengagement, the pilot bearing is probably defective.

Sometimes, the clutch assembly will have a rattle, especially when the clutch is fully engaged and there is no foot pressure acting on the linkage. A possible source of the rattle is a clutch fork that is loose on its pivot ball. The rattle may be caused by too much clearance between the fork and the groove in the throwout bearing. A loose fit between parts of a rod-and-lever linkage or a missing tension spring can cause the mechanism to rattle. It may be possible to tighten the clutch fork retainer clips or springs to reduce clearances and quiet the linkage.

Rattles can also be caused by weak pressure plate retracting springs in the diaphragm-spring pressure plate

assembly, or by weak or broken clutch disc cushion springs. Rattles stemming from these problems are usually loudest when the clutch is disengaged.

Loose flywheel attaching bolts cause movement at the mounting surfaces of the crankshaft and flywheel. This movement causes a deep knocking noise that is often mistaken for an engine main bearing or rod bearing knock. The noise may be accompanied by vibration. It can usually be reduced by disengaging the clutch. Pressure from the throwout bearing, acting through the release levers or fingers and the clutch cover, press the flywheel tightly against the crankshaft, quieting the knock.

Hard Pedal Effort

Hard pedal effort is noticed when the clutch pedal is excessively hard to push down. If the pedal is hard to depress, the problem is usually in the linkage. If the driver is strong enough to depress the pedal, it may stay on the floor or rise very slowly when released. Components may wear quickly.

To isolate the cause of the problem, disconnect the clutch linkage at the clutch fork and try to move the pedal by hand. If the clutch pedal does not move easily, the problem is somewhere in the linkage.

Where rod-and-lever linkages are concerned, hard pedal effort is due to lack of lubrication or to some part of the linkage that is bent or loose enough to jam. Sometimes, a rock or other material gets thrown up and jams the linkage.

Clutch pedals of cable linkages usually are hard to depress because moisture has entered the cable sheath. Moisture washes out the cable lubricant and causes corrosion. It is also possible that the cable was misrouted during installation and needs rerouting. If the cable is kinked as a result of misrouting, it should be replaced.

Clutch pedals of hydraulic linkages are hard to depress because of master cylinder or slave cylinder problems. The piston sometimes sticks due to internal corrosion. The usual cause, however, is swollen piston seals. This problem is a result of using a petroleum-based oil, such as automatic transmission fluid, instead of brake fluid (DOT 3 or DOT 4) to refill the reservoir. Petroleum-based oils will cause the seals to swell, jamming the piston in the cylinder. When this occurs, the seals must be replaced.

A less common cause of hard pedal effort in a hydraulic system is a swollen hydraulic hose. If the hose swells so that the fluid passageway becomes fairly constricted, it will take longer to actuate the slave cylinder piston. The swollen hose will slow clutch disengagement. It will also slow clutch reengagement and pedal return.

If the clutch linkage worked as it should when it was disconnected—that is, if it moved easily—the problem is in the clutch assembly. The two most common causes are a throwout bearing collar that is sticking on its hub or binding in the clutch fork. This usually occurs after the vehicle has been operated in deep water, causing water to enter the clutch housing and wash off the lubricant.

If the pedal is very hard to work after a new pressure plate assembly is installed, the pressure plate apply springs may be stronger than necessary. This is very common when a heavy-duty or competition (racing) pressure plate is installed. Return springs that are too heavy might be responsible for hard pedal effort. Remember, as you depress the clutch pedal, you are working against return-spring tension.

In-Car Clutch Service

Clutch service commonly requires the removal of major components, such as the drive shaft assembly, transmission, and clutch assembly. However, certain clutch problems can be attended to without removing these major components. This type of service is categorized as **in-car service**. Clutch repairs that fall into this category are clutch adjustment and linkage repair or replacement. Procedures are given in this section.

Clutch Adjustment

Clutch adjustment involves setting the correct amount of free play in the clutch linkage. Too much free play can cause clutch drag, preventing the clutch from ever fully disengaging. In this case, the power flow is not completely cut off from the clutch and the engine could continue to propel the vehicle. Too little free play can cause the clutch to slip. In this case, the throwout bearing rotates continually as it contacts the rotating pressure plate release levers or fingers, and it quickly wears out. With enough pressure on the levers or fingers, the clutch slips, overheats, and becomes damaged.

No matter what type of clutch linkage is used, the free play can be checked by pushing the clutch pedal with your hand. Refer to **Figure 7-5** and the next few paragraphs for the proper procedure.

Begin with the pedal in a fully released position—that is, with the pedal all the way up. Start pushing down on the pedal. The pedal should move easily for about 1" (25 mm). In this span, the only pressure you are working against is that of the return springs. Past this point, the pedal becomes harder to push. This is where the throwout bearing contacts the pressure plate release levers or fingers, and you are working against the force of the pressure plate apply springs.

The distance that the pedal moved from the fully released position until it became hard to push is the free play. All vehicle manufacturers specify the proper amount of clutch free play. Free play is adjusted at some place on the clutch linkage. On many vehicles, the clutch has a self-adjusting feature that automatically adjusts free play whenever the clutch pedal is depressed.

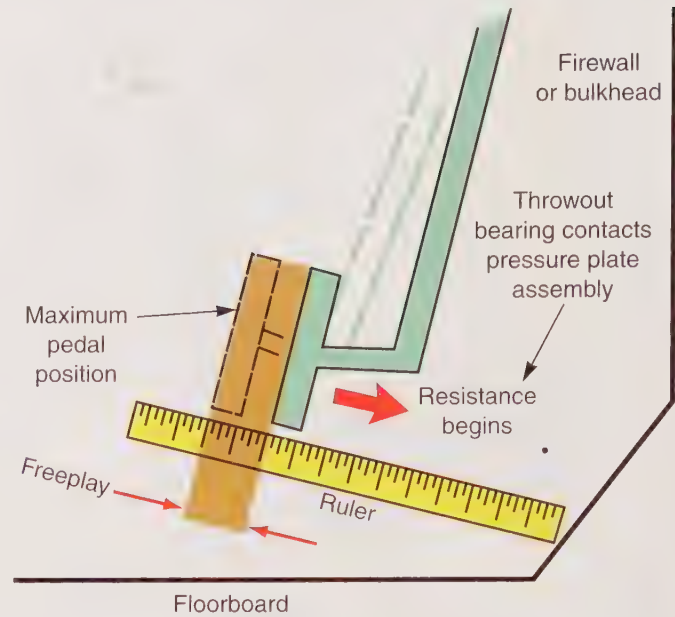


Figure 7-5. Free play can be measured using a ruler. The amount of free play should match the manufacturer's specifications. A general check can be made by observing the pedal movement. The throwout bearing first contacts the pressure plate assembly at the point where resistance is first felt when pressing on the pedal.



Note: A slipping clutch that is badly worn or damaged cannot be repaired by adjustment. If adjustment does not stop clutch slipping, or if enough free play cannot be obtained (indicating worn parts), the clutch assembly must be removed and worn parts must be replaced.

Rod-and-lever linkage adjustment

A rod-and-lever linkage is a series of links, levers, and rods connecting the clutch pedal to the clutch fork. Adjustment is usually provided by a threaded rod that passes through a pivot block, **Figure 7-6** and **Figure 7-7**. An adjustment device is located on the linkage at the clutch fork.

To adjust a rod-and-lever linkage, measure the actual amount of free play at the clutch pedal and compare it to specifications. Use a ruler to make an accurate measurement. If the specifications are not available, 1" (25 mm) of free play is usually close. Before attempting to make the adjustment, check that the linkage is not worn excessively. A loose, sloppy linkage cannot be satisfactorily adjusted.

Next, for the single-locknut adjuster, loosen the locknut that holds the threaded rod to the pivot block. Turn the rod until the proper free play is obtained at the clutch pedal and then retighten the locknut. For the double-locknut adjuster, loosen the one locknut, depending on which way the adjustment is to be made. Then, turn the other locknut in the same direction, advancing the pushrod until

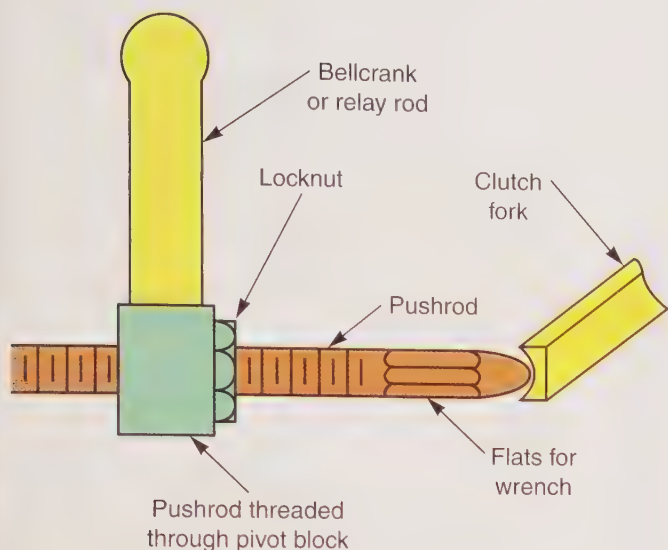


Figure 7-6. This shows a single-locknut adjuster. The locknut is loosened and the pushrod is turned in or out to obtain the proper free play.

the proper free play is obtained at the clutch pedal. Retighten the first locknut. Recheck the free play at the clutch pedal. As a final check, road test the car to check clutch operation.

Cable linkage adjustment

The cable linkage uses a cable to connect the clutch pedal to the clutch fork. Adjustment is made by a threaded section, which passes through a bracket. This section is located on the end of the cable linkage at the clutch fork. See **Figure 7-8**.

Some cables are self-adjusting. If there is no free play on a self-adjusting clutch, the adjustment mechanism is faulty or

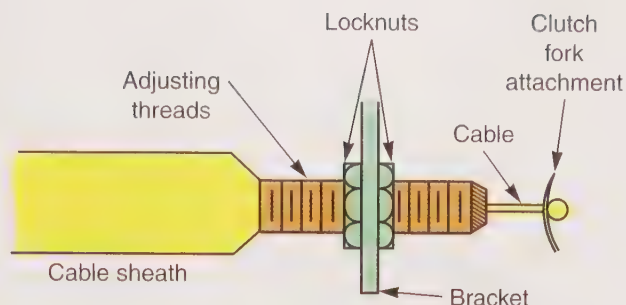


Figure 7-8. Adjusting free play in a cable linkage. The end of the cable is threaded. Loosening the locknuts and moving the cable makes the adjustment.

the clutch is worn out. Note that in many vehicles with self-adjusting clutch systems, the throwout bearing is always in contact with the release levers or fingers. Such bearings are called **constant-duty throwout bearings**. With the clutch pedal fully released, the bearing makes light contact with the release levers or fingers. Even so, there is enough slack in the cable linkage to give some free play at the pedal.

If the clutch is the manually adjustable type, use a ruler to measure the actual amount of free play at the clutch pedal. Compare the amount against the manufacturer's specifications. If the specs are not available, you can assume that the free play is between 1" and 1.5" (25 mm and 38 mm). Also, check that the cable and other linkage work freely and do not bind.

If the free play must be adjusted, loosen the locknut holding the threaded portion of the cable sheath. There are usually two locknuts holding the end of the cable to a bracket. Leave the locknuts loose and alternately turn them until the cable length is correct. Tighten the locknuts and recheck the free play at the clutch pedal. Then, road test the car and check clutch operation.

Hydraulic linkage adjustment

The hydraulic linkage uses hydraulic pressure to transfer pedal movement to the clutch fork. As with the previous adjusters, adjustment is made by a threaded section on the linkage at the clutch fork. Adjustment to this linkage changes the effective length of the pushrod at the slave cylinder. See **Figure 7-9**.

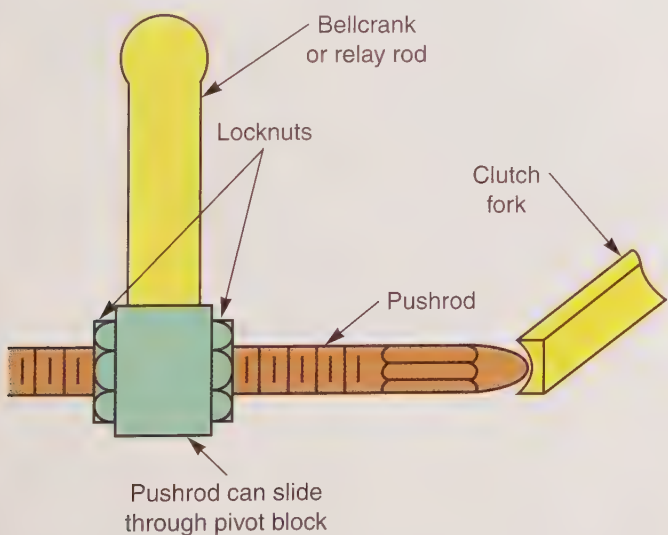


Figure 7-7. This shows a double-locknut adjuster. One locknut is backed away, the other is turned in the same direction to adjust the pushrod length. Note that the pushrod slides through the hole in the pivot block.

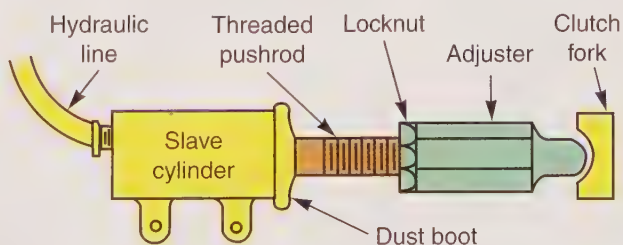


Figure 7-9. Adjusting free play in a hydraulic linkage. The pushrod is often threaded. Shortening or lengthening the rod adjusts free play. The pushrod is held by a locknut.

Measure the amount of free play at the clutch pedal. Use a ruler to obtain an accurate reading, and compare it against specifications. If the specifications are not available, between 1" and 1.5" (25 mm and 38 mm) of free play is generally acceptable.

Before adjusting free play, check the master cylinder reservoir to make sure the fluid level is sufficient. Add DOT 3 brake fluid if necessary.



Caution: *Never add motor oil, transmission fluid, or any kind of petroleum-based oil to the master cylinder reservoir. Use brake fluid only to prevent major damage to seals!*

Loosen the locknut holding the threaded rod to the adjuster. Turn the rod until you obtain the proper free play as measured at the clutch pedal. Retighten the locknut. Recheck the free play at the clutch pedal. Then, road test the car.

Clutch Linkage Repair and Replacement

Check the clutch linkage for proper operation. One of the most common points of wear in the linkage is the pedal itself. Bushings can wear, or the mounting bracket bolts can loosen. Always check these parts when servicing the clutch linkage or overhauling a clutch. **Figure 7-10** shows typical clutch pedal components.

Rod-and-lever linkage

A rod-and-lever linkage usually wears at pivot points. See **Figure 7-11**. Many pivot points contain metal or plastic bushings. These bushings often wear out.

Sometimes, linkage rods or levers will bend. This may happen if something in the clutch causes excessive resistance in disengagement. Another common cause of

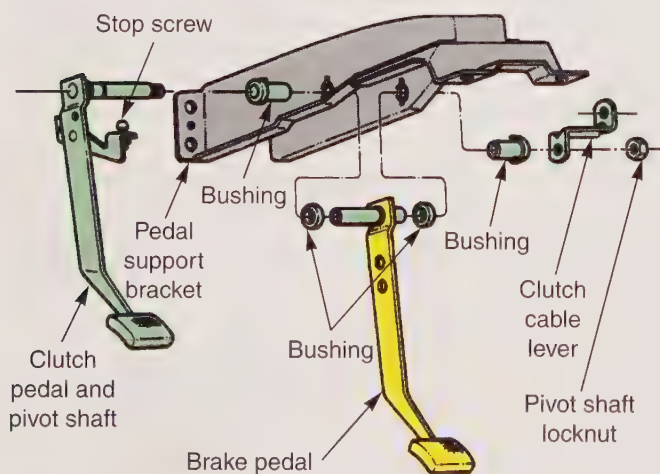


Figure 7-10. Study the exploded view of a typical clutch and brake pedal assembly. The pivot points should be carefully checked and lubricated. (Chrysler)

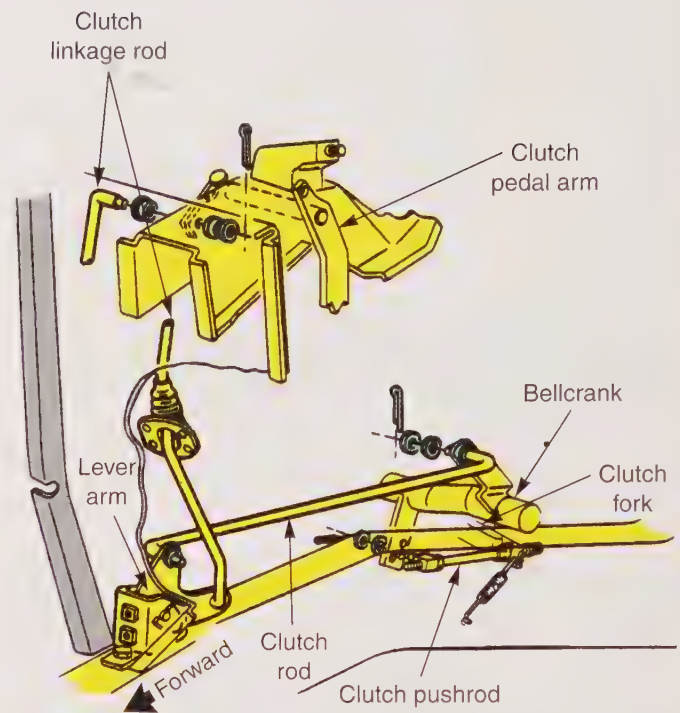


Figure 7-11. Notice the pivot points in this exploded view of a rod-and-lever linkage. Most problems in this system are caused by wear, misadjustment, or lack of lubrication at the pivot points. (General Motors)

problems is a bellcrank that binds or is loose because of worn motor mounts or misalignment of the engine in the vehicle. The linkage must be restored to perfect operating condition before the clutch will operate properly. This may involve lubrication, adjustment, or replacement of linkage parts.

Cable linkage

Cable linkage problems are usually due to a seized or binding cable assembly. Cables can seize due to corrosion or lack of lubrication. A cable may seize or bind if it is caused to kink in its sheath from improper routing. Defective cables should be replaced.

If a cable must be replaced, make sure you route it so there is no possibility of seizing or binding. Use all the original cable brackets and mounting locations if possible. A typical cable arrangement is shown in **Figure 7-12**.

Hydraulic linkage

Before adjusting a hydraulic linkage, always check the fluid level in the master cylinder reservoir first. If the fluid level is low, check for leaks at the places indicated in **Figure 7-13**. Leaks appear as dark stains on hydraulic system parts. Sometimes the brake fluid used in the system is visible at the point of the leak. Leaks can occur in the hydraulic lines or at loose connections. The most common leaks, however, occur at the master or slave cylinder seals.

It is usually easier and cheaper to replace leaking master and slave cylinders. However, in some cases, a

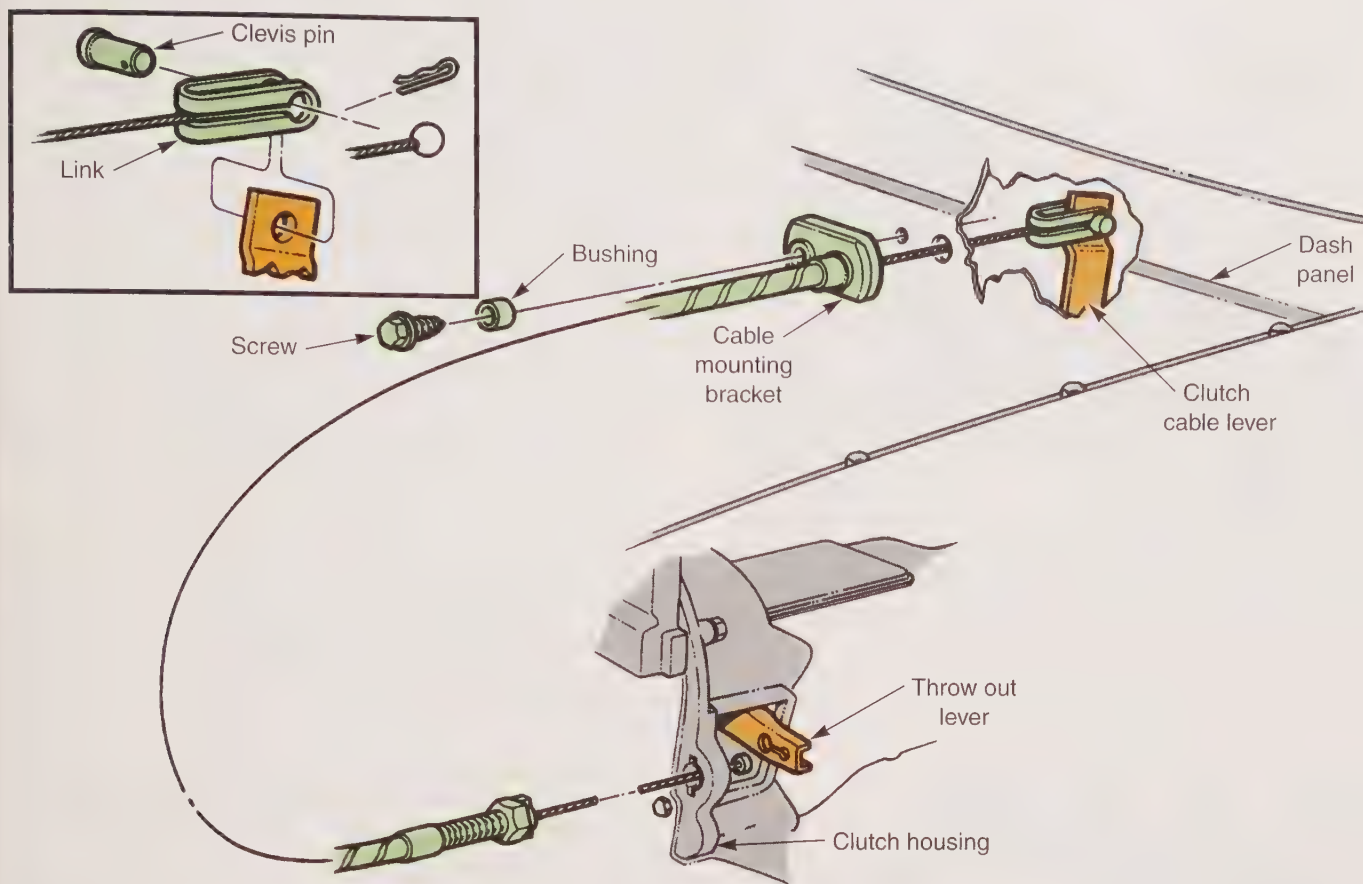


Figure 7-12. This is a typical cable linkage. A replacement cable must be routed so that it does not seize or bind. The original routing is normally the best. (Chrysler)

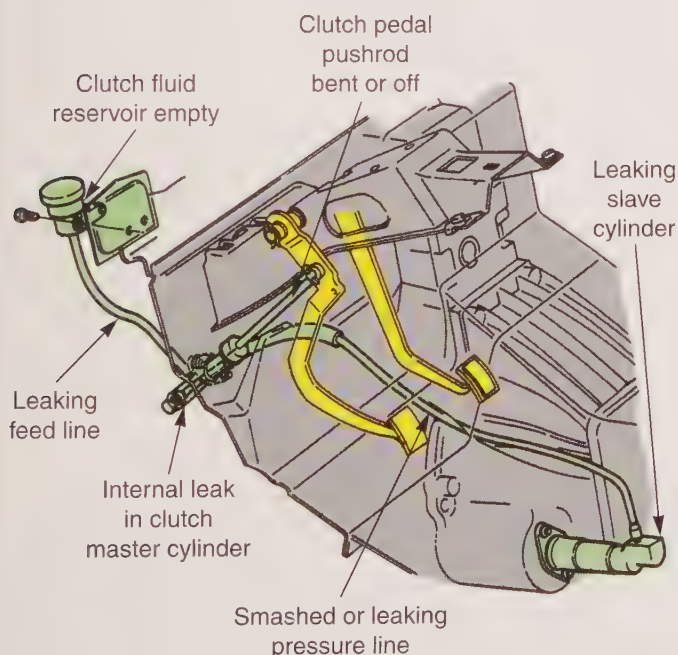


Figure 7-13. Common sources of hydraulic linkage problems are shown. The pushrod for actuating the master cylinder piston may be bent or disconnected, but most problems are caused by low fluid level or by plugged hydraulic lines. Leaks are usually responsible for low fluid levels. Kinks can cause plugging of hydraulic lines. (Ford)

replacement cylinder is not available, or the cost of replacement is excessive. If a new or remanufactured master or slave cylinder cannot be located, the old cylinder can be rebuilt with the proper seal kit.

Rebuilding a master or slave cylinder is relatively simple. It is similar to rebuilding brake system cylinders. Refer to the exploded views of typical master and slave cylinders in **Figure 7-14**. Following is a typical rebuilding procedure:

1. Remove any rubber boot that covers the free end of the piston.
2. Remove the snap ring that holds the piston in the cylinder bore. The piston should slide out of the cylinder. In some cases, the piston will pop out of the cylinder because of a return spring behind it. If the piston is stuck, it can be removed by tapping the cylinder on a wooden block or by carefully applying air pressure to the inlet connection.



Warning: Air pressure can cause the piston to fly out with great force. Point the open end of the cylinder away from yourself and others and toward rags or some other soft surface before applying pressure.

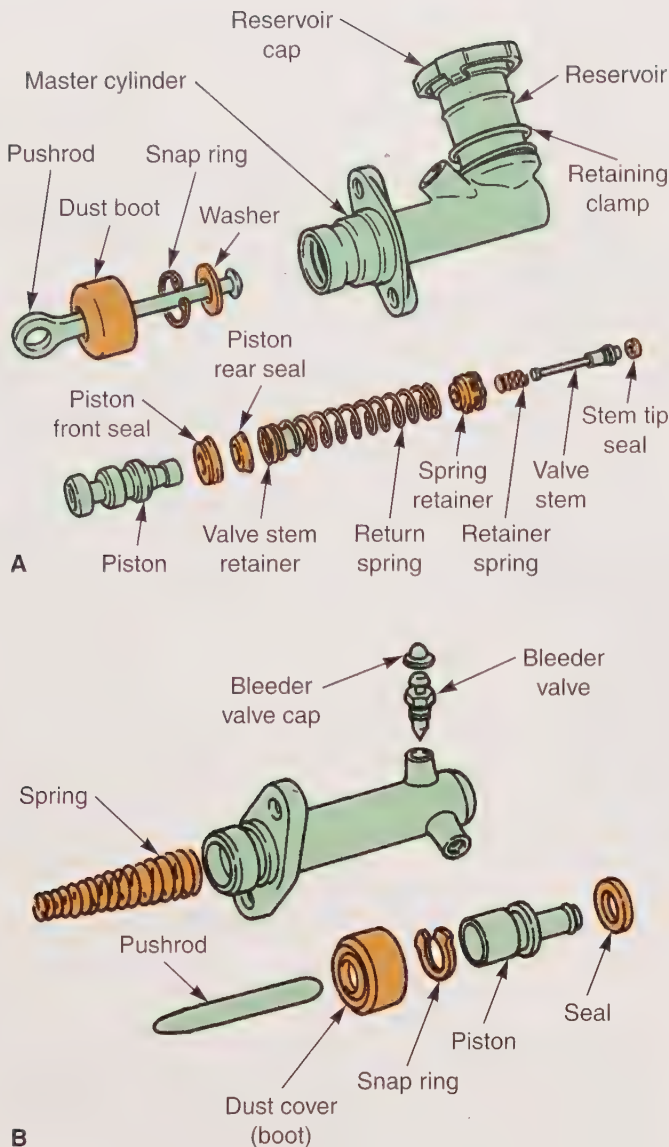


Figure 7-14. Study the exploded views of master and slave cylinders. A—A master cylinder is shown. The shape, the included parts, and their layout can vary. The manufacturer's service manual should be consulted for an exact breakdown of parts. B—A slave cylinder is shown. It, too, can vary as to parts, shape, and layout. (Chrysler, General Motors)

- Once the piston is out, inspect the cylinder for wear or pitting. If the cylinder bore is worn or pitted, the cylinder must be replaced. Remove the old seals from the piston and discard them. Thoroughly clean all parts and allow them to dry.



Caution: Do not allow any petroleum-based solvent to remain on the cylinder or piston.

- Install the return spring, when there is one, in the cylinder.

- Obtain new seals. Make sure they are the correct ones. Lubricate them with brake fluid, *never* with petroleum-based lubricants, and install them on the piston.
- Install the piston in the cylinder. Be careful not to damage the new seals.
- Install the retaining snap ring, pushrod, and boot.
- Install the rebuilt cylinder.
- Attach the hydraulic line. There should be no air in hydraulic lines; if there is, it must be removed by bleeding the lines. If the hydraulic system was disassembled for any type of repairs, you must bleed the lines to remove the air. Once the bleeding operation is finished, pressure on the pedal should apply the clutch firmly. There should be no spongy-pedal feel.

The slave cylinder has a **bleeder valve** for bleeding air from the system. The valve looks like a screw with a small hole running down its length. The hole is closed off when the bleeder valve is tightened down. Loosening the valve a few turns will open the hole and permit system bleeding. Note that some bleeder valves have a cap, as well.

There are two methods to manually bleed air from a hydraulic system. One method is preferred over the other because it minimizes the chance of fluid contamination. This preferred method is outlined as follows:

- Fill the system reservoir with fresh brake fluid. Leave the cover off the reservoir. (Bleeder valve is closed.)
- If the bleeder valve has a cap, remove it at this time. Attach a hose to the end of the bleeder valve. Place the free end of the hose in a clear container. Fill the container with enough fluid to cover the bottom of the hose.
- Have an assistant pump several times on the clutch pedal. Then, ask the assistant to hold the pedal down.
- Open the bleeder valve by loosening it about a quarter or half turn. Make sure your assistant continues to keep his or her foot on the clutch pedal. The pedal will probably go all the way to the floor. Air, or a mixture of air and brake fluid, will come out of the bleeder valve. Keep the outlet of the hose submerged in the fluid as it begins to fill the container. Watch for air bubbles.
- Close the bleeder valve once the flow stops.
- Let up on the clutch pedal.
- Repeat the process until only brake fluid comes out of the bleeder valve. This can be noted by watching the air bubbles emerging from the hose as the system is bled.
- Top off the system reservoir with fresh brake fluid, and put the cover back on the reservoir. Do not reuse fluid bled from the system, as it may be contaminated.

There is an alternative method of bleeding air from a hydraulic system. It can be done without an assistant and without wasting brake fluid; however, expelled fluid,

which may be contaminated, is returned to the system. The method is outlined as follows:

1. Open the bleeder valve by loosening it about a quarter or half turn.
2. If the bleeder valve has a cap, remove it at this time. Attach a hose to the end of the open bleeder valve. Place the free end of the hose in a clear container of brake fluid.
3. Fill the system reservoir with fresh brake fluid, and replace the cap.
4. Pump the clutch pedal until bubbles stop coming out of the hose in the container. You might want to have an assistant watch for the bubbles for you to make the job easier.
5. With the clutch pedal released, close the bleeder valve.

Clutch Removal

The exact procedure for clutch removal varies according to the engine and drive train layout. On vehicles with rear-wheel drive and on many vehicles with front-wheel drive, the transmission and clutch are removed from the vehicle without removing the engine. On some front-wheel drive and on most rear-engine vehicles, the engine, clutch, and transaxle are removed from the vehicle as an assembly. When removed from the car, the components are separated to expose the clutch assembly. On other front-wheel drive vehicles, the engine and clutch are removed, leaving the transaxle in the vehicle. On a few vehicles, the clutch can be removed and replaced without removing any other components.

The following sections contain some general procedures for removing a clutch from a vehicle. Always refer to the appropriate service information for specific procedures.

Front-Engine, Rear-Wheel Drive

The following procedure details the proper way to remove a clutch from a front-engine, rear-wheel drive vehicle:

1. Disconnect the battery negative cable, **Figure 7-15**.



Warning: Always disconnect the battery ground cable before working near the clutch. Otherwise, if the starter is accidentally operated, you could be severely injured.

2. Raise the vehicle with an approved hoist or hydraulic jack. If using a hydraulic jack, be sure to install good quality jack stands under the vehicle frame before getting under the vehicle.

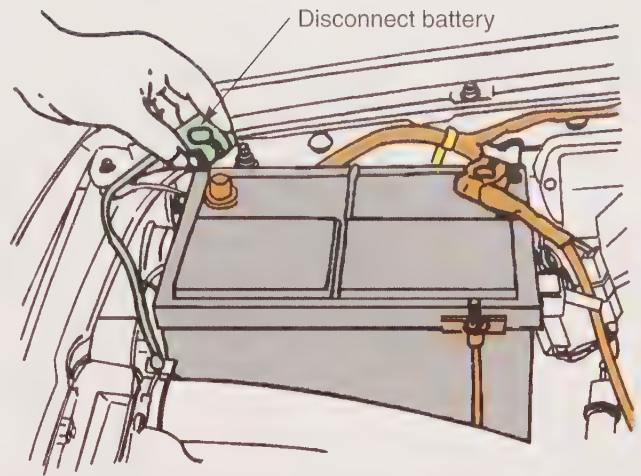


Figure 7-15. The battery should always be disconnected at the ground terminal before beginning any clutch repairs. If the battery is not disconnected, there is always a possibility that the starter will be operated, causing injury. (Subaru)



Warning: Never work under a vehicle supported only by a hydraulic jack. Always support the vehicle with jack stands.

3. Once the vehicle is properly raised and supported, remove the drive shaft assembly. (Chapter 13 covers this in detail.) Cap the rear of the transmission to prevent oil dripping. See **Figure 7-16**. If the vehicle has four-wheel or all wheel drive, remove the front drive shaft from the transfer case.



Warning: If the vehicle has been operated recently, the engine and exhaust system will be hot. Always be careful when working on a hot engine.

4. Disconnect the pushrod or cable and return spring connected to the clutch fork.
5. Remove the transmission. (Chapter 9 covers transmission removal in detail.) On many vehicles, the clutch housing and transmission case are combined in a single casting. In such cases, the clutch housing is removed along with the transmission by removing the unit from the back of the engine. Note that the transmission input shaft and front bearing retainer are removed with the transmission. In addition, the clutch fork and throwout bearing assembly are removed with the one-piece, or integral-type, casting. If the vehicle has a transfer case, the transmission and transfer case can be removed as a unit.

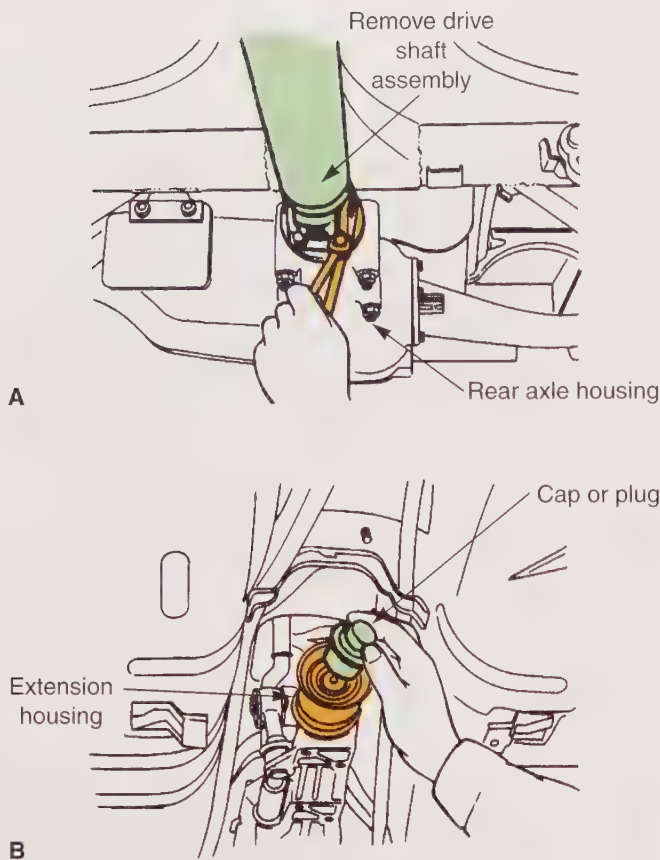


Figure 7-16. The first steps to remove a clutch. A—Remove the drive shaft assembly. B—Cap the transmission extension housing to prevent oil loss. Oil leakage can create a safety hazard. (Subaru)



Warning: Support the engine when removing the transmission. Usually, the transmission provides some support for the engine. Removing it removes this support.

Also, use a transmission jack, **Figure 7-17**, to support the transmission. Never let the transmission hang unsupported once attaching bolts connecting the transmission to the clutch or engine are removed. This can cause damage to the clutch disc splines or transmission input shaft. Make sure, for this and for other reasons, you support the transmission at all times. If a transmission were to fall, it could cause injury or damage. Be especially careful when lowering a transmission and transfer case combination, as the weight of the transfer case is usually off-center.

6. Remove as much dust as possible from inside the bellhousing with an approved vacuum collection system designed for use with asbestos fibers, in particular.

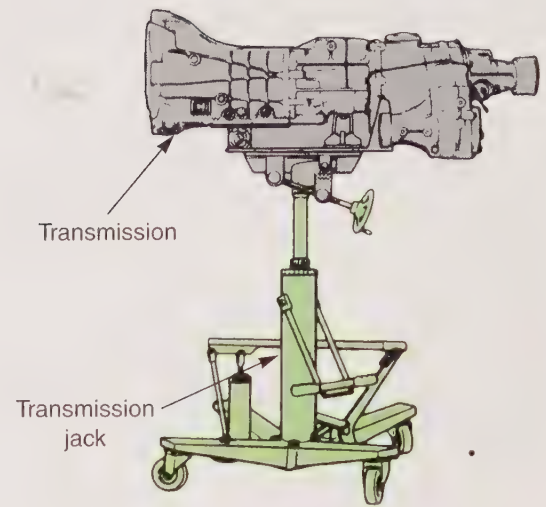


Figure 7-17. Transmissions are heavy. Use a transmission jack to support and lower the transmission from the vehicle. (Owatonna Tool)



Warning: Some clutch discs contain asbestos—a powerful cancer-causing substance. Avoid breathing dust from inside the bellhousing or clutch assembly. Do *not* blow dust off these components with compressed air.

7. Remove the throwout bearing from the clutch fork. If the clutch fork pivots on a ball stud, remove the fork at this time. Most clutch forks are held to the ball stud by spring clips. See **Figure 7-18**. In many cases, the clutch fork can be removed by pushing (or pulling) the inner end toward the front of the housing while pulling the other end straight out.
8. If still in place, remove clutch housing from the back of the engine. (Integral-type clutch housing was removed with transmission.) To do this, remove the clutch access cover from the front of the housing. Then, remove the clutch housing attaching bolts (clutch housing-to-engine bolts). Vacuum any dust inside the housing.
Note that housing removal is not necessary in every case. In some vehicles, the clutch assembly may be removed through an opening provided by removal of a clutch access cover.
9. If the pressure plate assembly and flywheel do not have dowels or offset bolt holes for alignment purposes, use a punch to mark the original position of the clutch cover relative to the flywheel. Beforehand, vacuum any dust from the clutch. Typical punch marks are shown in **Figure 7-19**.
10. Insert a pilot shaft, or clutch alignment tool, through the clutch disc hub and into the pilot bearing, if desired. This will keep the clutch disc from falling out of the pressure plate assembly as the clutch cover attaching bolts (clutch

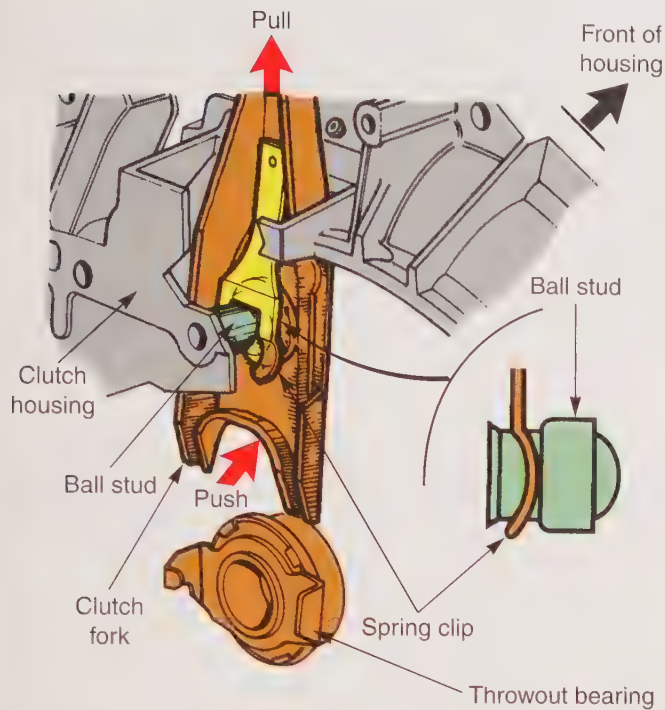


Figure 7-18. Clutch forks that pivot on a ball stud are usually held in place by a spring clip. Remove the clutch fork by pushing the inner end forward and pulling on the outer end. (Chrysler)

cover-to-flywheel bolts) are being removed. Note that an old transmission input shaft makes a good pilot shaft.

11. Loosen the clutch cover attaching bolts sequentially, one turn at a time, until all spring pressure is relieved. If bolts cannot be reached, use a flywheel turner to rotate the flywheel until each bolt is accessible. Once pressure is relieved, carefully remove the bolts and the pressure plate assembly. Then, remove the clutch disc and alignment tool from the flywheel.



Warning: The pressure plate assembly is fairly heavy. Make sure you can support its weight before removing the last bolt. If a clutch alignment tool has not been used, be aware that the clutch disc could fall out as the attaching bolts are removed.

Also, if the clutch was slipping, it may be hot for a long time after the vehicle is stopped. Be careful not to burn yourself on a hot pressure plate or flywheel.

12. With the clutch removed, check the engine-to-transmission mounting surface for cracks and foreign material that would prevent proper engine-transmission mating. Also check the core (freeze) plugs at the rear of the engine block for corrosion, leaks, and proper installation. Check the rear seal for oil leaks and damage. If dowel pins are used for engine and clutch housing alignment, check them for burrs or bending. If there are no dowel pins, ensure that they have not been lost. Check the dowel pin holes for elongation and burrs.

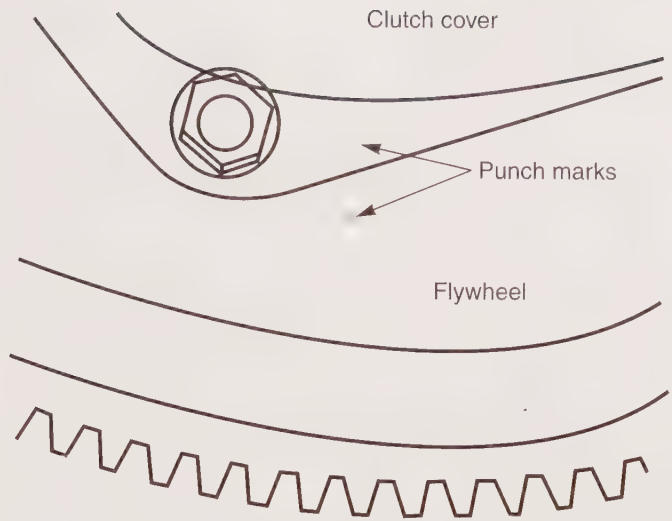


Figure 7-19. To maintain the proper balance between the reassembled flywheel and the pressure plate assembly, make punch marks on both parts before disassembling. This is necessary only if the pressure plate will be reused.

In many cases, this completes clutch removal. You should inspect the pilot bearing and flywheel (outlined in upcoming paragraphs) and determine if they must also be removed.

Front-Engine, Front-Wheel Drive

The following procedure details the proper way to remove the clutch from a front-engine, front-wheel drive vehicle. Note that with a few exceptions, the general procedure, cautions, and warnings duplicate clutch removal for front-engine, rear-wheel drive vehicles.

1. Disconnect the battery negative cable.



Warning: Always disconnect the battery ground cable before working near the clutch. Otherwise, if the starter is accidentally operated, you could be severely injured.

2. Raise the vehicle with an approved hoist or hydraulic jack. If using a hydraulic jack, be sure to install good quality jack stands under the vehicle frame before getting under the vehicle.



Warning: Never work underneath a vehicle supported only by a hydraulic jack. Always support the vehicle with jack stands.

3. Once the vehicle is properly raised and supported, remove the drive axles. There are several variations of front drive axle attachment. On some vehicles, the wheels and brake assembly, along with certain steering and suspension parts, must be removed to remove

the axles. On other vehicles, the drive axles can be removed without removing these parts. (This is covered in detail in Chapter 15.)



Warning: If the vehicle has been operated recently, the engine and exhaust system will be hot. *Always* be careful when working on a hot engine.

4. Disconnect the pushrod or cable and return spring connected to the clutch fork.
5. Remove the transaxle. (This is covered in detail in Chapter 11.) On many vehicles, the transaxle and clutch housings are a single unit, **Figure 7-20**. If this is the case, the complete unit is removed from the engine. On vehicles requiring the engine also be removed for clutch replacement, refer to the manufacturer's service manual.

Note that the transmission input shaft and front bearing retainer will be removed along with the transaxle. In addition, the clutch fork and throwout bearing assembly will be removed with the one-piece, or integral-type, casting.



Warning: Support the engine with an engine holding fixture when removing the transaxle. This will keep the engine from dropping as you remove the transaxle and will protect the motor mounts.

Also, use a transmission jack to support the transaxle. Never let the transaxle hang unsupported once attaching bolts connecting the transaxle and clutch housings are removed. This action can cause damage to the

clutch disc splines or transmission input shaft. Make sure, for this and other safety reasons, that you support the transaxle at all times. If a transaxle were to fall, it could cause injury or damage.

From here, the clutch removal procedure duplicates that for front-engine, rear-wheel drive vehicles. To complete clutch removal, continue with step 6 of that section.

Clutch Parts Inspection and Repair

With the clutch removed, each component must be carefully inspected for wear and damage. Be sure all parts are clean before inspection. Clean the flywheel face and pressure plate with a nonpetroleum-based cleaner. Do not wash the throwout bearing in any kind of solvent. Do not get grease on the clutch disc facings.

Look for any signs of damage or wear, no matter how slight. After the defect is identified, the concerned part(s) may be repaired or replaced. Service procedures for the various related parts of the clutch are the focus of this section.

Pilot Bearing Service

A worn pilot bearing will allow the transmission input shaft and clutch disc to wobble. This can cause clutch vibration, a noisy clutch, and damage to the transmission. Pilot bearings are relatively cheap, and they are easy to change while the clutch is being serviced.

Bearing inspection

The clutch pilot bearing is not serviced until the clutch is removed. The bearing is often worn out by then. The pilot bearing should be inspected for excessive wear

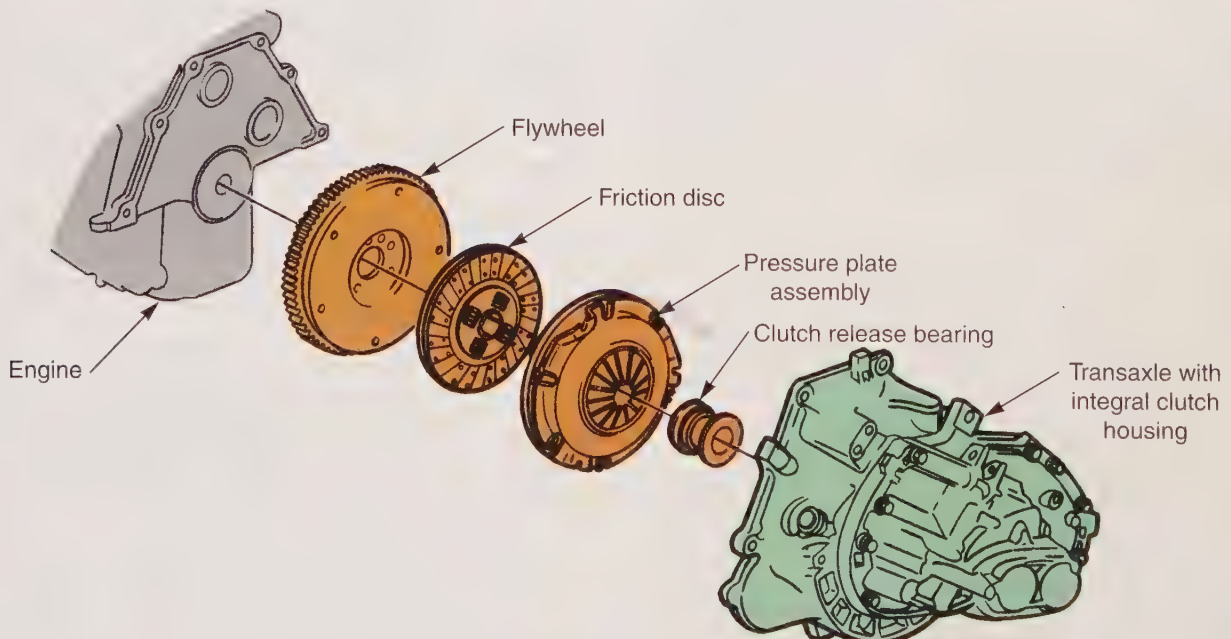


Figure 7-20. The clutch housing and transaxle case are usually combined into a single casting. (General Motors)

or damage. Some technicians will automatically replace the bearing as a matter of practice. If there is any doubt about a pilot bearing's condition, it should be replaced!

Roller- or ball-type pilot bearings should be inspected for lack of lubrication. To check this, turn the bearing and feel for roughness. If it does not turn smoothly, it should be replaced.

In a pilot bushing, wear will show up as looseness between the bushing and the input shaft pilot. A good way to check for looseness is to insert a used input shaft into the bearing and try to wiggle it. If it has too much play, the bushing is worn out and it should be replaced.



Note: To perform this check, you must have the same type of input shaft as used in the vehicle transmission.

Bearing removal

There are a couple ways to remove a pilot bearing. One way is to use a pilot bearing puller tool, as shown in **Figure 7-21**. One variation of this tool is the threaded-tip puller. The threaded-tip puller is used to remove a pilot bushing, but it ruins the bearing in the process. The center shaft, or pilot, of this tool has a self-tapping tip. The pilot is threaded into the bore of the bearing. When fully inserted, the legs of the puller are adjusted to seat on the crankshaft flange. As the tool is tightened further, it pulls the pilot bearing from the crankshaft bore. Another variation, called an expandable finger-tip puller, is a similar tool used when ball or roller bearings are used.

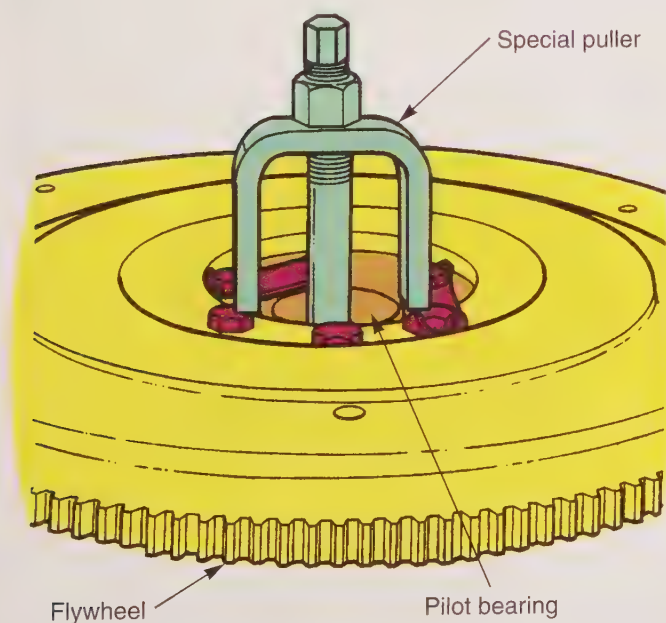


Figure 7-21. The pilot bearing removal tool will make pilot bearing removal easier. (Chrysler)

Another way to remove the old pilot bearing is to pack the recess behind the bearing with heavy grease. Then, install a driver into the pilot bearing—an old input shaft works nicely. Put on eye protection and strike the exposed end of the input shaft with a hammer. The force from the hammer will travel through the input shaft to the grease. The grease will push the bearing from the crankshaft. See **Figure 7-22**.

Bearing installation

Before installing the new pilot bearing, slip it over the pilot of the transmission input shaft. This is done to ensure it is the proper bearing. If it will not slip over the shaft, or if the fit is too loose, it is not the correct bearing.

The next step is to drive the new bearing into the crankshaft bore, **Figure 7-23**. Use a properly sized driver to avoid damage. Measure the installed depth of the pilot bearing. If this depth is too shallow, the input shaft may contact the bearing. This will damage the bearing, the input shaft, or both. If the bearing is driven in too deeply, it may not make full contact with the input shaft pilot. This is not a problem with bushings, as they are usually longer. If bushings are driven in too deeply, there is still usually adequate surface contact with the input shaft pilot.

Once the pilot bearing is properly installed, lubricate it with a small quantity of high-temperature grease. Most bearings have a recess behind the bearing. A small amount of grease stored in this recess will find its way to the bearing surface, helping to keep it supplied with lubricant. See **Figure 7-24**.

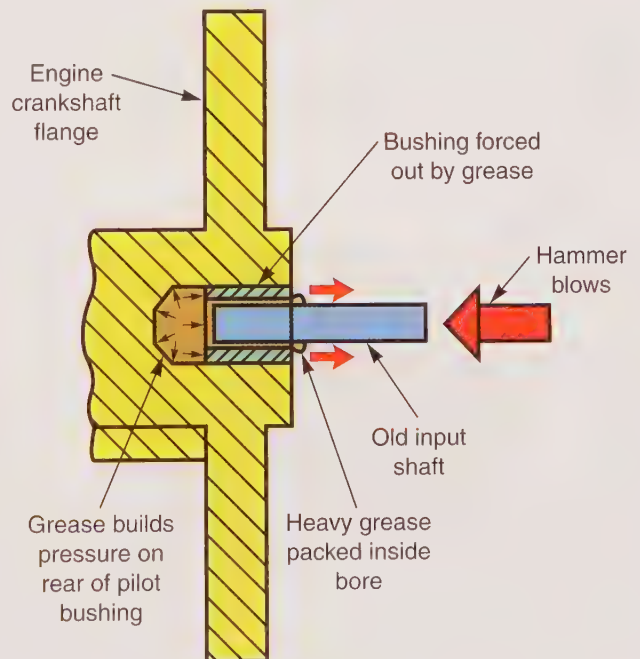


Figure 7-22. A pilot bearing can also be removed by packing grease into the recess behind the bearing. A driver is then placed into the pilot hole and struck. The driver moves into the grease, creating pressure. The pressure drives out the bearing.

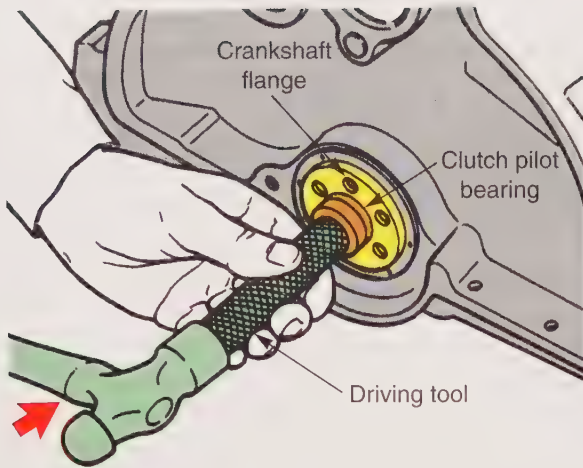


Figure 7-23. A new pilot bearing should be installed with the proper bearing driver. Use a driver that contacts the outer race only when driving a roller- or ball-type pilot bearing. Always be very careful to avoid damage when installing a new bearing. (Ford)



Caution: Do *not* put too much lubricant on the bearing or in the recess. Excess lubricant will be thrown out of the pilot bearing and can ruin the clutch disc. Note that some bearings are prelubricated and do not require any additional lubrication.

Flywheel Service

The flywheel is large and very heavy, and removing it can be difficult and even dangerous. It should not be removed unless it is in need of resurfacing. It is rare to find a flywheel that is not showing some sign of wear or overheating. Judgment is called for in deciding if it must be resurfaced. In many cases, the flywheel can be reused without machining. If the flywheel is not badly worn, it can be cleaned by light sanding.

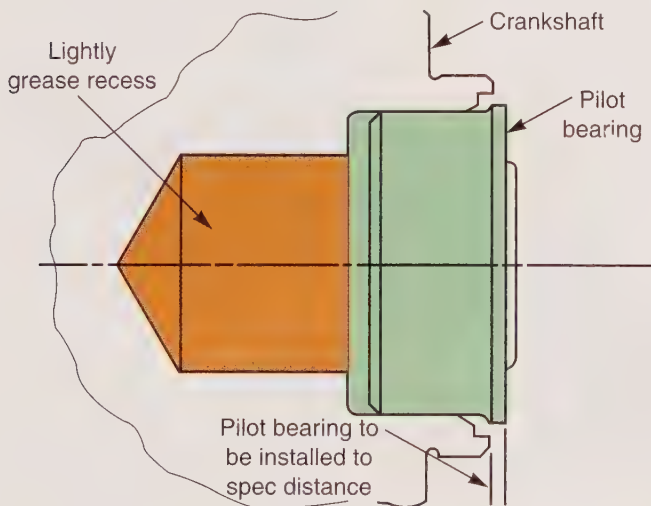


Figure 7-24. Grease the recess behind the pilot bearing, but be careful to use only a small amount. Lack of grease will allow the bearing to run dry and be damaged. On the other hand, too much grease will drip out and damage the clutch disc. (Ford)

Flywheel inspection

Visually inspect the flywheel for obvious signs of damage. Check the flywheel machined surface for discoloration (caused by overheating), scoring, or extremely shiny surfaces. In some cases, the flywheel may have deep heat cracks. Look for warping. Inspect the threads in the holes for the clutch cover attaching bolts. If they are stripped, they can be restored by installing a thread repair insert. Also, check the flywheel ring gear for damage. If even one ring gear tooth is broken, the ring gear must be replaced. Note that if the ring gear teeth are damaged, you should also check the teeth of the starter drive pinion for damage.

If the flywheel is not obviously damaged, use a straightedge and feeler gauge to check for warped contact surfaces. Manufacturers' specifications as to maximum warpage vary. As a general rule, if more than a 0.01" (0.25 mm) feeler gauge fits under the straightedge, the flywheel must be resurfaced.

A dial indicator also can be used to check for a warped flywheel. In addition, it can be used to check the flywheel runout. Push the flywheel toward the engine to remove crankshaft endplay. Then, mount the dial indicator on a stationary part of the engine with the indicator point bearing on a smooth, relatively undamaged part of the machined flywheel surface, as shown in **Figure 7-25**. Rotate the flywheel and watch the dial to determine how much fluctuation in values there seems to be, which would give an indication of warping. If, rather than a series of fluctuations, the dial shows a steady increase for half a turn and then a steady decrease, flywheel runout may be excessive. In either case, the flywheel must be removed and resurfaced or repositioned.

To check warpage, zero the dial indicator; then, slowly turn the flywheel through about a quarter of a revolution. Watch the indicator face and note if displacement ever exceeds 0.01" (0.25 mm). Without moving the indicator,

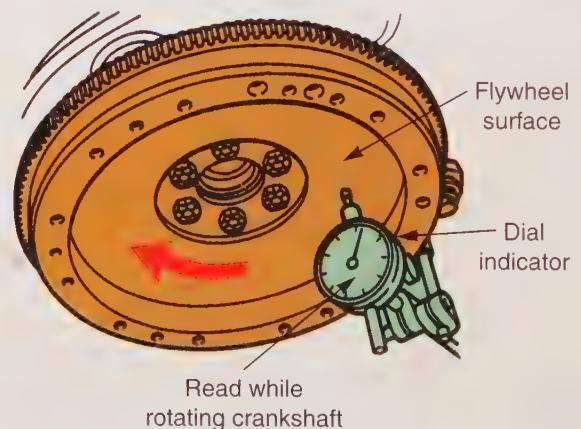


Figure 7-25. Proper mounting of the dial indicator is important. The base must be solidly attached to the rear of the engine. Push on the flywheel to remove crankshaft endplay. Position indicator so that plunger just touches the flywheel. The dial is then zeroed. (Ford)

repeat this procedure at least three more times at different positions on the flywheel. If any of the samples produce fluctuations exceeding 0.01" (0.25 mm), the flywheel must be resurfaced.

As mentioned, the surface of the flywheel should also be checked for **runout**. This is a condition of a rotating object, such as a shaft or flywheel, in which the surface is not rotating in a true circle or plane. **Radial runout** is a measure of out-of-roundness. It is measured at right angles to the centerline of an object. Excessive radial runout may be caused, for example, by a bent shaft. **Lateral runout** is a measure of in-and-out movement, or wobble. It is measured in the direction that is lengthwise to the centerline of the rotating object. In other words, it is measured on the plane surface of the rotating object. Excessive lateral runout can result, for example, if a flywheel is not mounted properly.

To check for lateral runout, slowly rotate the flywheel while watching the dial indicator. Determine the lowest point on the flywheel, which corresponds to the lowest reading on the dial. Zero the indicator at this point. Move the flywheel until the highest reading is recorded. This measurement is the lateral runout.

Lateral runout should not exceed the manufacturer's specifications. If it does, the flywheel may not be mounted properly. Remove it and check for burrs between the flywheel and the face of the crankshaft flange. If no burrs exist, check the runout of the crankshaft flange.

Note that while the dial indicator is mounted, you can also measure crankshaft endplay. Push the flywheel forward and rearward and note the displacement on the dial.

Flywheel removal

The easiest way to remove the flywheel attaching bolts is with an impact wrench. If you do not have an impact wrench to remove the flywheel, it must be kept from rotating so the attaching bolts can be loosened. While the bolts are being removed, the flywheel can be held in place using a flywheel turner or locked in place with a flywheel holder; alternatively, a block of wood can be placed between the flywheel and a stationary part of the engine.



Warning: Always wear eye protection when using an impact wrench.

A flywheel is very heavy. It can cause injury or severe damage if dropped. Do *not* remove the bolts completely until you have the flywheel secured so that it cannot fall.

Once the flywheel is securely held, the bolts can be loosened and the flywheel can be removed. Sometimes there is a flat metal spacer between the flywheel and the crankshaft flange. The spacer should be saved for reassembly.

After removing the flywheel, check the rear main bearing seal for leaks. If the seal is leaking, oil could reach the new clutch disc and ruin it, just as it may have ruined the old disc. A leaking seal must be replaced.

Flywheel repair

Some flywheels may be damaged beyond repair. Others may be repaired and then reinstalled. Some of these may be fixed by replacing the ring gear or by resurfacing.

Flywheels with damaged ring gears are usually replaced. Some ring gears can be removed from the flywheel and replaced, **Figure 7-26**.

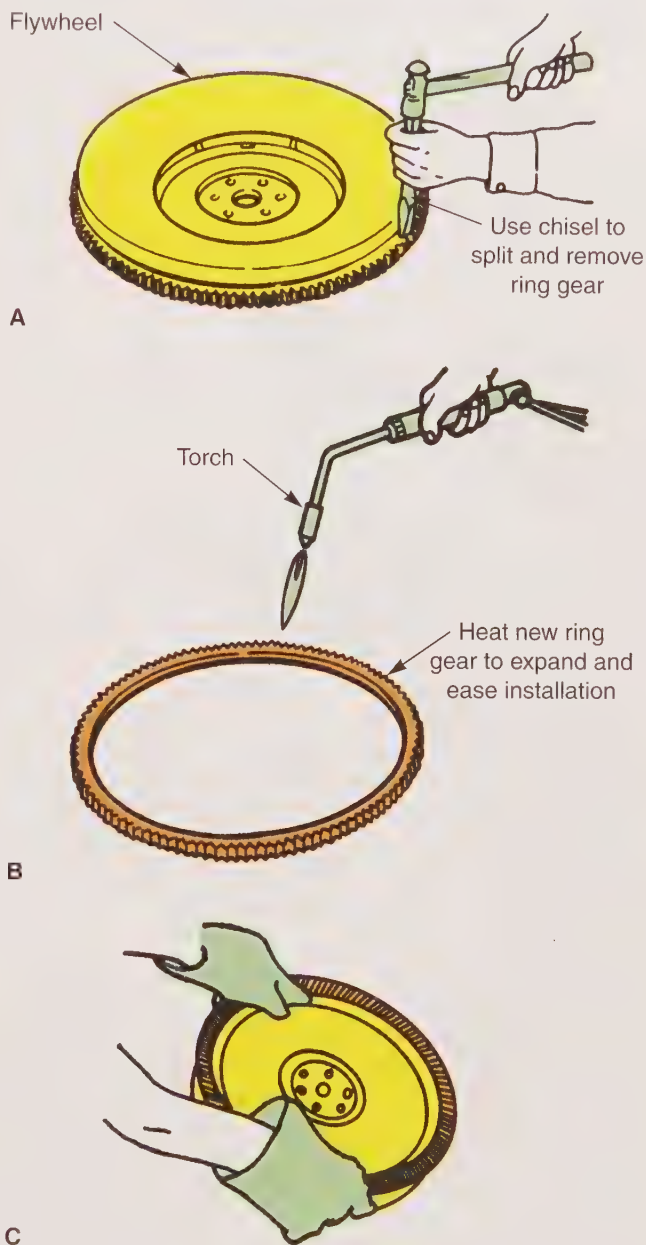


Figure 7-26. Most manual transmission flywheels have a removable ring gear. **A**—A chisel is being used to remove the ring gear from a flywheel. Be careful not to damage the flywheel. **B**—You should heat the replacement ring gear with a torch or in an oven. Be careful not to overheat the ring gear, or the metal will lose its strength. **C**—Place the new ring gear over the flywheel and ensure that it is properly seated. Always wear gloves or use tongs to prevent burning your hands when handling the hot ring gear. (General Motors)

Some flywheel ring gears are welded into position; others are a shrink fit. If it is determined that the ring gear is to be replaced, it can be cut from the flywheel with a cutting torch or a metal saw. Ring gears that are welded are commonly removed by breaking the welds with a chisel. Those that are a shrink fit can be heated and then removed with a chisel. See **Figure 7-26A**.



Warning: Wear eye protection during ring gear removal.

If the new ring gear is to be installed by a shrink fit, you can expand the gear by heating, **Figure 7-26B**, or shrink the flywheel by cooling. Usually, the easiest method is to heat the ring gear with a torch. Try to heat the part evenly. Once the ring gear is hot enough (close to but *not* exceeding 450°F [232°C]), it can be placed over the flywheel, **Figure 7-26C**.



Caution: Wear welding gloves when handling the hot ring gear or handle it with tongs.

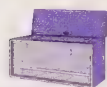
After the ring gear is placed on the flywheel, it should be checked for proper seating. Make sure the gear is not warped; warpage will cause the starter to jam. Once you have determined that the ring gear is properly installed, stake it or weld it in place, as necessary.

A cracked, scored, or severely overheated flywheel must be resurfaced. A severely cracked flywheel must be replaced. Be sure the replacement flywheel has its balance weights (thickened areas on flywheel) in the proper position. The easiest way to do this is to compare the old and new flywheels. Therefore, never dispose of the old flywheel until reassembly is complete.

Resurfacing a flywheel is a job for a machine shop. Generally speaking, any machine shop that can resurface cylinder heads can resurface a flywheel. The machining process for flywheels is similar to that for cylinder heads.

Flywheels can be resurfaced by turning on a lathe (including a brake lathe), cutting on a milling machine, or grinding on a table with a special grinding wheel. No matter what method is used, the basic process is the same: material is removed until the surface is totally clean and damage-free.

Only a certain amount of metal can be removed, however. If too much is removed, the flywheel will not have sufficient metal to absorb heat. Some flywheels are marked to indicate the maximum amount of metal that can be removed. If the flywheel is not marked, the machine shop will usually be able to tell you if there is enough good metal left in the flywheel. As a general rule, about 0.2" (5 mm) can be removed from a flywheel that has not been machined before.



Note: If you placed alignment marks on the flywheel face, they will be removed during the machining process. Make a duplicate mark at the exact spot on the back of the flywheel. Some flywheels have alignment dowels. These dowels should be removed before the flywheel is sent to the machine shop for resurfacing.

Flywheel installation

Once the flywheel is resurfaced, it should be reinstalled in its original position. First, reinstall any alignment dowels. Solid dowels are installed by driving them in squarely with a soft-faced mallet. A special tool with a shoulder is needed to drive hollow dowels. Drive the dowels in carefully until they are fully seated. If there was a spacer plate between the flywheel and the crankshaft flange, reinstall it before replacing the flywheel.

Align the crankshaft flange and flywheel bolt holes. They are usually spaced so they will line up at only one location. After the bolt holes are aligned, start the flywheel attaching bolts. Torque the bolts to the proper tension in a crisscross pattern, **Figure 7-27**. Use a flywheel holder or a wood block to hold the flywheel during the tightening operation.



Caution: Do *not* tighten the bolts with an impact wrench. The bolts must be torqued properly.

Flywheel resurfacing

The flywheel is held to the crankshaft flange with special hardened bolts. Do *not* use any other kind of bolt. Be careful not to accidentally swap the flywheel attaching bolts with any others.

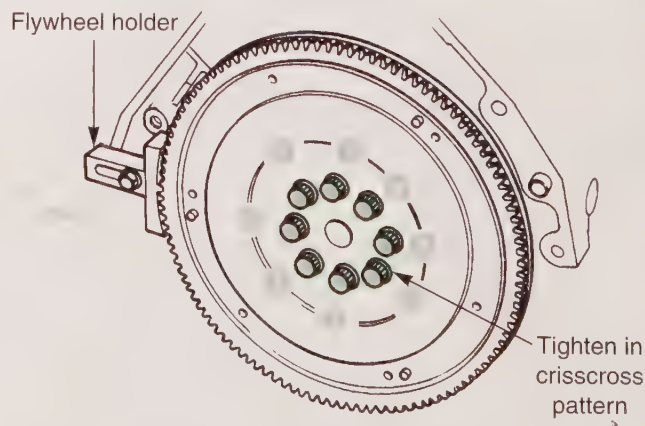


Figure 7-27. Torque the flywheel attaching bolts in a crisscross pattern. Be sure to use the proper bolts and torque them to specification. Do not use an impact wrench to tighten the bolts. (Honda)

Clutch Disc Service

In most cases, the clutch disc is replaced when any kind of clutch teardown is done, since it is relatively inexpensive. If the disc was recently replaced or appears to be in excellent condition, it can be reused. Before deciding to reuse the disc, it should be carefully checked.



Warning: Asbestos dust is harmful. Avoid breathing any dust from the clutch disc, as it can contain large amounts of cancer-causing asbestos. Even new clutch discs often contain some asbestos.

If you intend to reuse the clutch disc, do not wash it in any kind of cleaning solvent. Solvent will ruin the clutch disc friction facings.

Inspect the clutch disc for thin or cracked friction material. The disc thickness can be checked with a sliding caliper, as shown in **Figure 7-28**. Usually, however, other indications will be obvious and this step will be unnecessary. Check the disc for loose rivets, oil-soaked friction facings, or broken cushion springs. Make sure the hub flange splines are not worn and they slide freely on the splines of the transmission input shaft. If the clutch disc shows any wear or damage, it should be replaced. **Figure 7-29** shows various types of clutch disc damage you might find during inspection, along with possible reasons damage occurred.

If a replacement disc is to be used, it must be carefully compared to the old one before it is installed. Many clutch problems are caused by installing the wrong replacement disc. It is especially important to check the hub flange size against the old disc. A hub flange that is too large will contact the flywheel and pressure plate, causing clutch disc damage and gear clash. As a final check, slip the replacement disc over the transmission input shaft to make sure it has the correct splines.

Pressure Plate Assembly Service

The pressure plate assembly is another clutch component that is almost always replaced when the clutch is repaired. You should spend a few moments checking the pressure plate assembly. This will help you determine the cause of the clutch problem and learn how it can be prevented in the future.

Pressure plate assembly inspection

The pressure plate machined surface develops the same problems as the flywheel surface. Check for wear, scoring, signs of overheating, cracks, and warpage. The pressure plate will usually show more heat damage than the flywheel.

Retaining rivets for diaphragm-spring pivot rings should be checked for looseness. Loose rivets indicate long usage or rough clutch treatment.

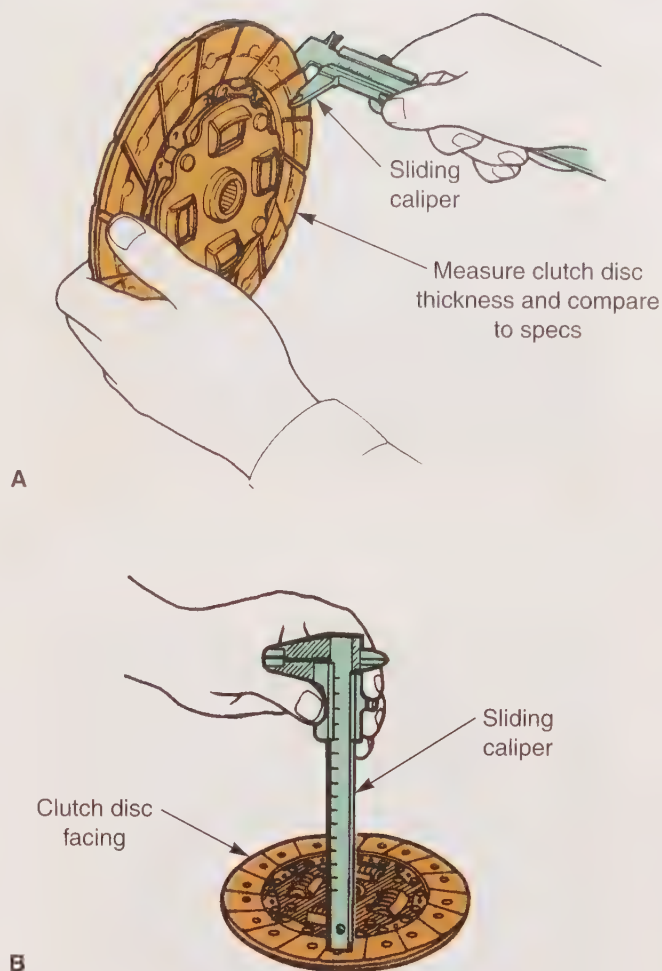


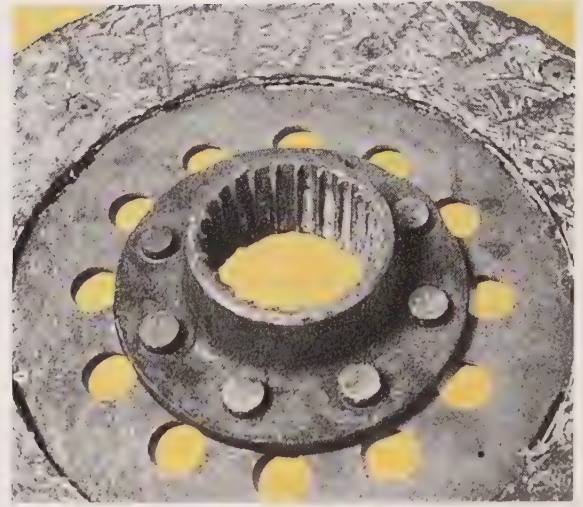
Figure 7-28. Inspecting the clutch disc. A—Clutch disc thickness can be measured with a sliding caliper. If thickness specifications are available, the thickness can be compared to determine whether the disc can be reused. B—Depth gauge on sliding caliper or depth micrometer can be used to determine the distance from the top of the clutch disc rivets to the surface of the friction facing. If the rivets are too near the surface, the disc is worn out and should be replaced. (Honda, Chrysler)

Elongation of the bolt holes in the clutch cover is an indication the clutch cover attaching bolts were loose. The pressure plate assembly may bounce against the flywheel if these bolts are loose, which would cause the holes to elongate.

Check for weak pressure plate springs and for signs of overheated springs. The release fingers or levers should be checked for wear and misadjustment. If any fingers or levers are lower than the others, the pressure plate application will be uneven. The clutch may grab or chatter. Severe wear at the contact point with the throwout bearing indicates the clutch has seen much use or there was no free play. **Figure 7-30** shows various types of pressure plate assembly damage you might find during inspection, along with possible reasons the damage occurred. This damage may range from chatter marks on the pressure plate to a scored pressure plate or broken release levers. Being able to readily identify the damage will result in better service times.



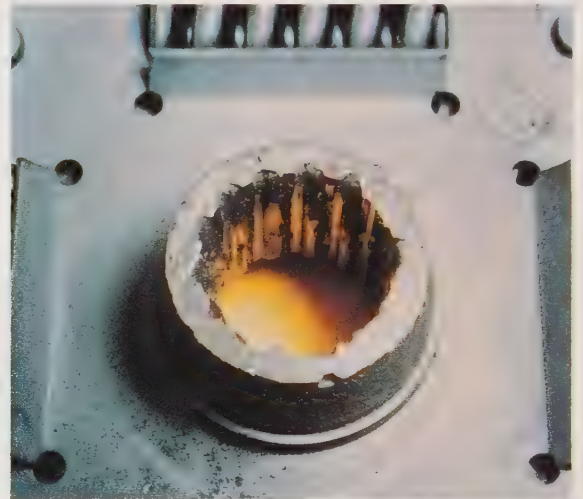
A—Burned disc facing—Oil contamination, slipping clutch, insufficient clearance adjustment.



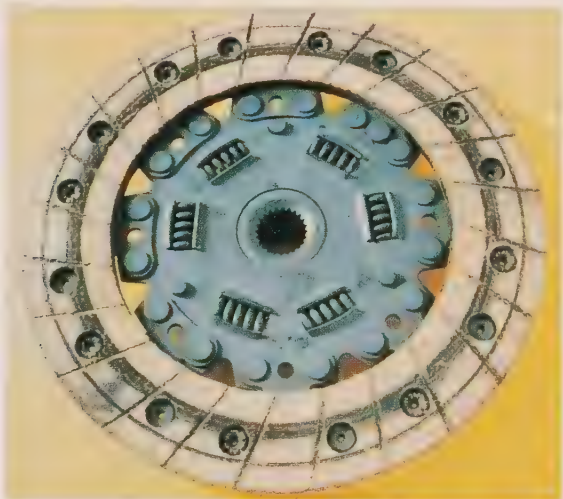
B—Hub splines worn—Improper engine-to-transmission alignment, damaged input shaft, bad pilot bearing.



C—Worn disc facing—Weak pressure plate springs, normal wear, scored or cracked flywheel.



D—Damaged hub splines—Transmission drawn into place with bellhousing bolts.

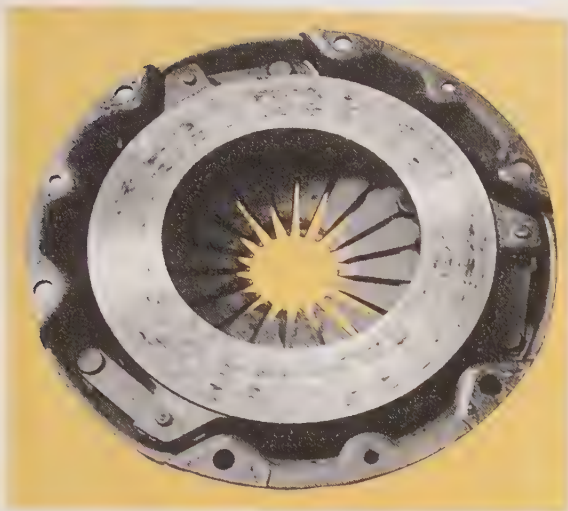


E—Scored disc facing—Flywheel not machined when needed, bad pressure plate reused.



F—Wear on hub—Installed backwards, wrong parts.

Figure 7-29. Study the types of clutch disc damage. (Luk)



A—Chatter marks on pressure plate—Oil or grease contamination, binding linkage, loose or soft motor mounts, worn driveline parts.



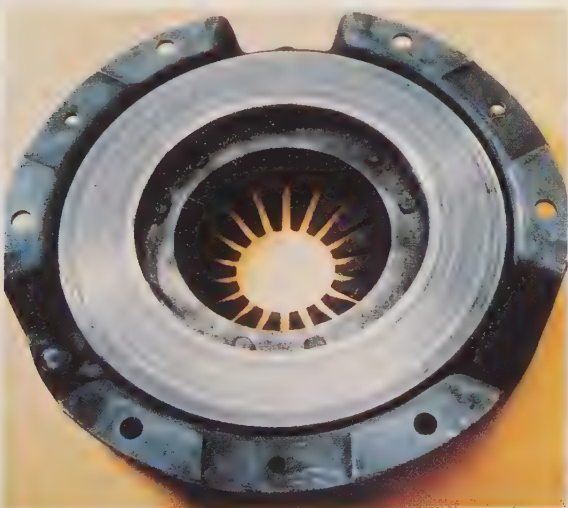
B—Broken pressure plate retracting spring—Normal fatigue, wrong clutch for vehicle, low-quality pressure plate.



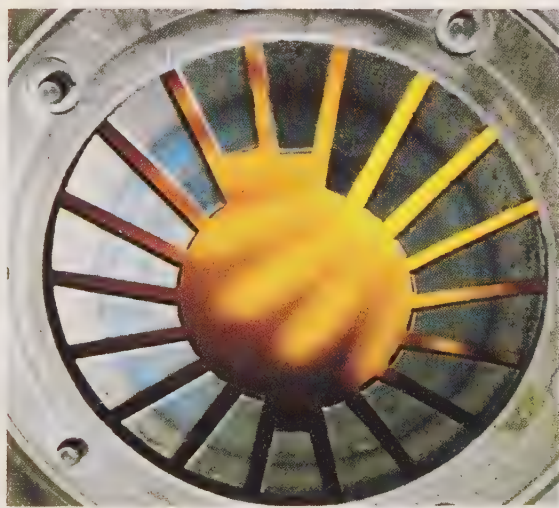
C—Pressure plate hot spots or heat checks—Clutch slippage, oil or grease contamination, clutch adjustment too tight, binding linkage, driving habits.



D—Broken release levers—No free play in clutch adjustment, bad release bearing, improper part alignment.



E—Scored pressure plate—Clutch disc worn to rivets, adjustment too tight, clutch slippage, binding linkage.



F—Broken diaphragm spring—Installation error, excessive pedal reserve causing throwout bearing to travel too far during disengagement.

Pressure plate assembly repair

Most repair shops choose to completely replace pressure plate assemblies, rather than rebuild them. It is possible, however, with the proper equipment, to take apart a pressure plate assembly and replace just the parts that are worn. This is typically done on an assembly line by large automotive rebuilders. As a general rule, pressure plate assemblies that are put together with nuts and bolts can be rebuilt, while pressure plates held by rivets cannot be rebuilt. If a shop decides to rebuild a pressure plate assembly, it must closely follow the manufacturer's directions. A general procedure for rebuilding a pressure plate assembly is shown in **Figure 7-31**. Remember to wear eye protection!

Throwout Bearing Assembly Service

The throwout bearing is almost always replaced when the clutch is serviced. It is often a source of problems. If

the bearing must be reused, it should be carefully checked for defects.

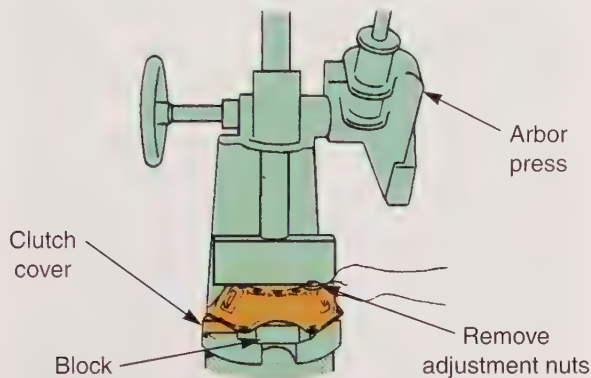


Caution: If you intend to reuse a throwout bearing, do not wash it in any kind of cleaning solvent. Solvent will dissolve the throwout bearing lubricant, which cannot be replaced.

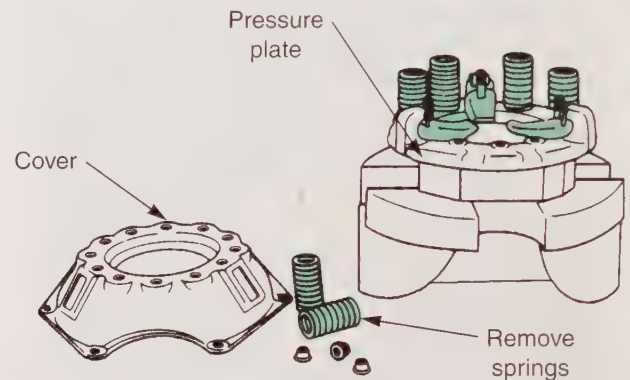
Throwout bearing assembly inspection

Check the throwout bearing for roughness by attempting to rotate it by hand. If rotation is rough, or if it appears to have lost its grease, it should be replaced.

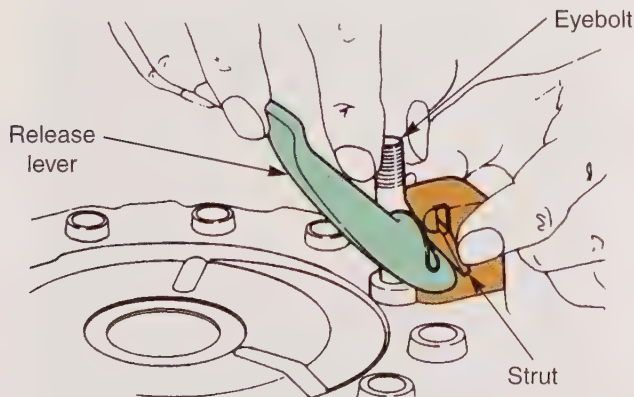
Check the bearing collar for a free (but not loose) fit on the hub of the transmission's front bearing retainer. A loose fit indicates that the collar or hub, or both, is worn. Check the collar where it contacts the clutch fork. If the



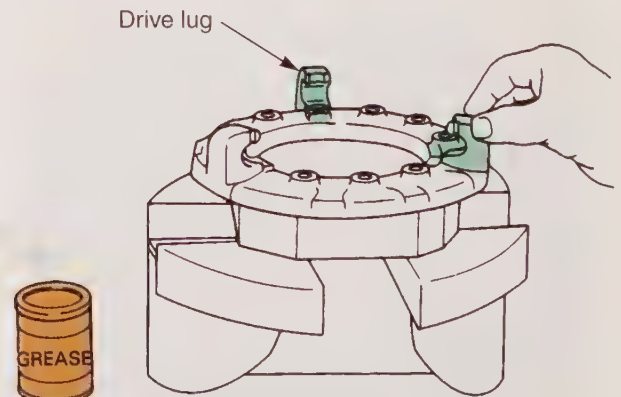
A—Use an arbor press to compress pressure plate apply springs so that the assembly can be taken apart. Place and arrange the block under the pressure plate so that the cover is free to move down. Remove the eyebolt adjustment nuts, which are used to adjust the release lever height, from clutch cover. Slowly release the arbor press so the cover can be removed without the apply springs flying out.



B—Carefully mark positions of all springs and release levers. This will ensure parts are reinstalled in their original positions. Organize the disassembled parts of the pressure plate assembly on the workbench. Replace all parts that show wear.

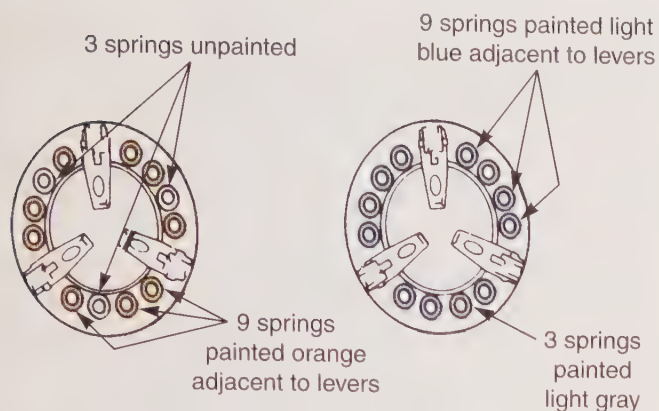


C—Remove release levers. To do this, lift up on the lever and remove the strut. Keep all parts of each particular lever together.

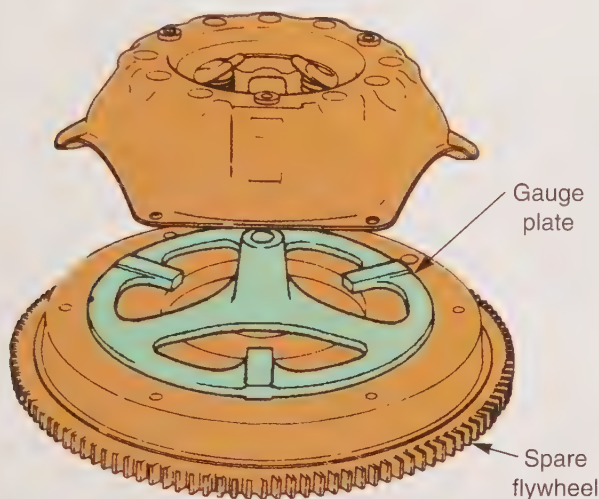


D—Grease the pressure plate drive lugs with high temperature grease, after inspecting assembly for cracking, wear, and other damage.

Figure 7-31. Procedures A through H illustrate the steps in a coil-spring pressure plate assembly overhaul. This procedure is general, and the manufacturer's service manual should always be consulted. (General Motors) (continued)



E—To reassemble, install the release levers and apply springs. Basically, install the release levers by reversing the procedure for removal. If new springs are used, install them using the sequence shown; otherwise, return the springs to their original positions.



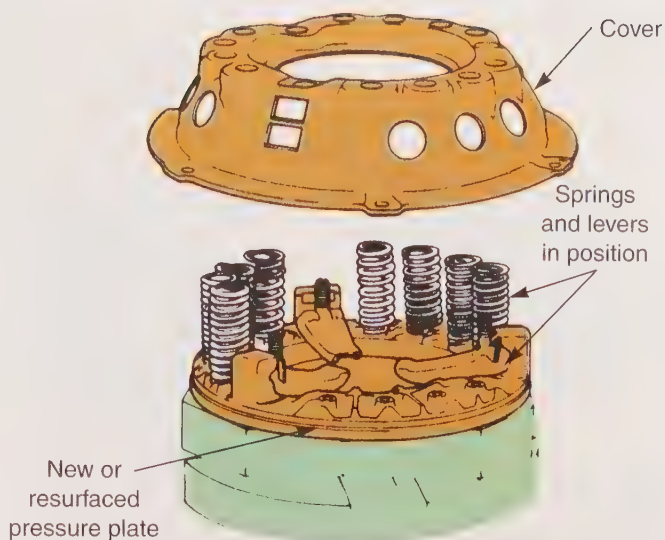
G—To ensure uniform clutch application, the release levers must be set to equal heights. Place the gauge plate on the spare flywheel, and place the pressure plate assembly over it. The gauge plate occupies the position normally occupied by the clutch disc and simulates installed component positions. Bolt the clutch cover to the flywheel. Note that spacers or shims may be used instead of gauge plate.

Figure 7-31. Continued

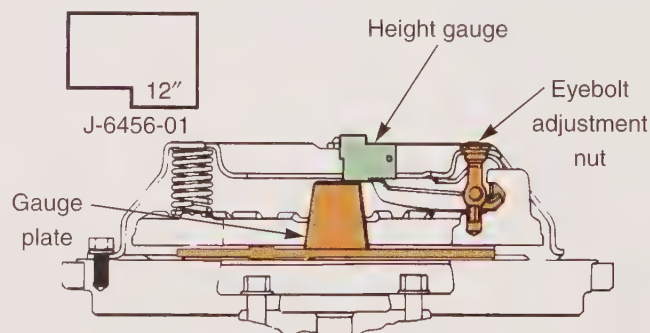
collar is worn, the fork usually is worn also. Any worn parts should be replaced. **Figure 7-32** shows damage related to the throwout bearing, which you might find during inspection, along with possible reasons the damage occurred.

Throwout bearing assembly repair

Some throwout bearings are an integral part of the bearing collar. These are replaced as a unit. Many throwout bearings, however, are a press fit onto the bearing collar. The assembly can be repaired by replacing the bearing or collar—whichever is in need of repair.



F—With the pressure plate assembly positioned on the arbor press as per original setup, slowly apply pressure to the clutch cover. The drive-lug openings in the clutch cover should fit over the drive lugs; apply springs should fit into their seats, as shown. Screw the eyebolt adjustment nuts onto the eyebolts until their tops are flush. Slowly release the arbor press and remove the assembly.



H—Position the height gauge on the hub of gauge plate. Turn the eyebolt adjustment nut until the lever is flush with the height gauge. Adjust all levers in this manner. Stake all adjustment nuts when finished so they will not loosen in service. A straight-edge can also be used and placed across the cover. Levers can then be set to a height at some specified distance down from the straightedge. Remove the clutch cover from the flywheel, loosening the bolts gradually until spring pressure is relieved.

Replacement bearings must be pressed onto the collar after the old bearing is removed. To remove the throwout bearing, press it from the collar using a bench vise or press. Adapters may be necessary to properly perform the pressing operation. Press on the new throwout bearing. It should be fully seated on the shoulder of the bearing collar when complete. Refer to **Figure 7-33**.



Caution: Do not apply driving force through the bearing elements when installing the throwout bearing.



A



B

Figure 7-32. A—Dry, worn throwout bearing—Riding clutch, improper clutch adjustment. B—Worn front bearing retainer hub—Bent fork or fork mount.

After the bearing is in place, rotate it by hand and make sure it rotates smoothly. It should turn without binding or roughness.

Clutch Fork Service

A bent or worn clutch fork can prevent the clutch from releasing properly. Inspect the clutch fork for such signs of damage. Look for wear at the throwout bearing mount. On lever-type clutch forks, check the pivot-point contact area. Inspect the spring clip that holds the clutch fork to the pivot point. On shaft-type clutch forks, check the pivot shaft for wear.

If inspection reveals a damaged clutch fork, the fork must be removed (if it is not already) and replaced. The lever-type clutch fork is removed when the clutch is

disassembled. The shaft-type clutch fork can be removed by first removing the pivot, or clutch release, shaft. The shaft is usually held by a clip, **Figure 7-34A**. Once the clip is removed, the shaft will slide out of the housing and the fork can be removed from the shaft, **Figure 7-34B**. With the fork assembly apart, you can also check the pivot shaft for wear.

Clutch Housing Service

Clutch housings usually are not a source of problems. It is important, however, that they be inspected for damage. Clean the clutch housing interior and exterior. Then check the housing for cracks and damage to mounting surfaces. Any damage is grounds for replacement.

Also, check the clutch fork ball stud for wear. It should be undamaged and tight. If the stud must be replaced, it can usually be removed from the clutch housing with a large Allen wrench or a differential-plug removal tool.

Clutch Installation

The following section presents the general procedures for installing a clutch safely and properly. The exact procedure for clutch installation varies according to the engine and drive train layout. You should always refer to the manufacturer's service manual for specific procedures and techniques to install a clutch safely and properly.

Front-Engine, Rear-Wheel Drive

The following procedure details the proper way to install a clutch in a front-engine, rear-wheel drive vehicle:

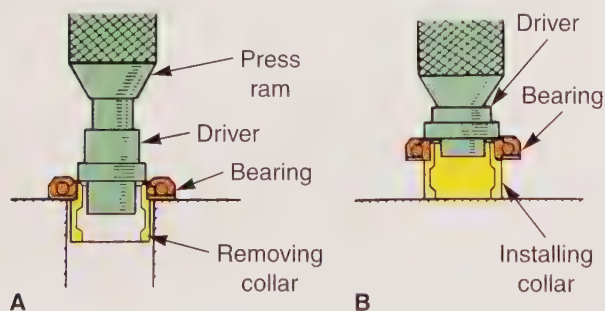


Figure 7-33. Replacing a throwout bearing. A—The throwout bearing can be removed from its collar by using a press. The proper adapter must be used. In many cases, the bearing can be removed and replaced by using a bench vise. B—This illustrates the bearing installation procedure. Be careful not to exert any pressure on the rolling elements or outer race. (Toyota)

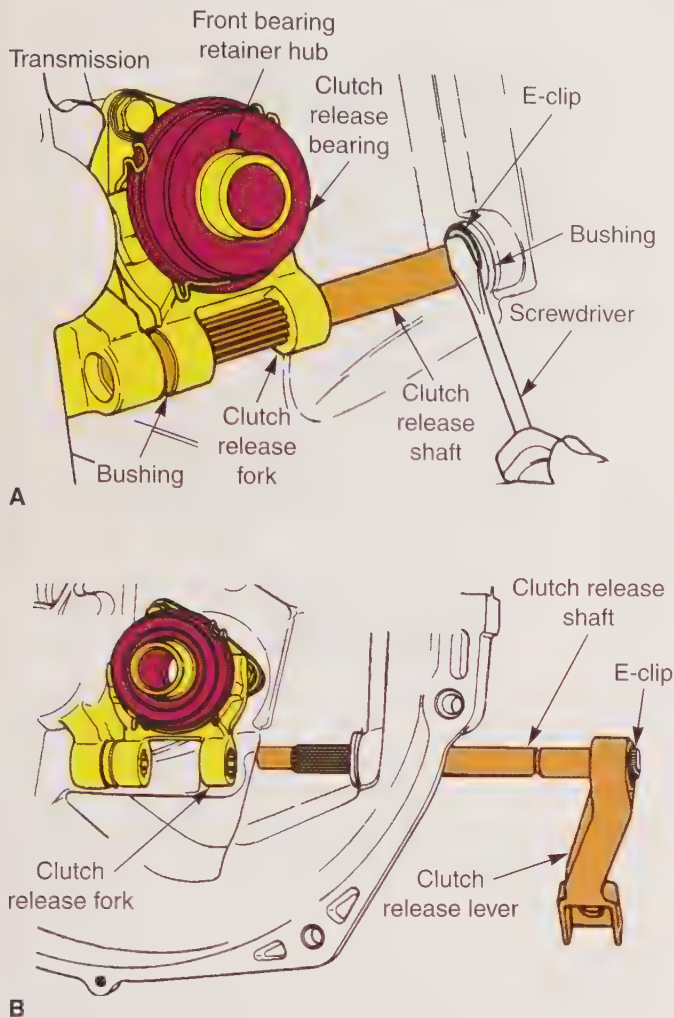


Figure 7-34. This type of clutch fork uses a shaft mounting. It must be disassembled to remove the fork. When the shaft is out of the housing, it should be checked for wear. A—Remove the retaining E-clip. B—Remove the clutch release shaft. (Chrysler)

1. Pilot bearing and flywheel installations were detailed previously in respective service sections. As a preliminary step, recheck the pilot bearing and flywheel to make sure they are installed properly.
2. Install the clutch disc and pressure plate assembly onto the flywheel. If one side of the disc is marked flywheel, place that side against the flywheel. If not marked, study the disc, flywheel, and assembly to determine which way the long side of the hub should fit into the assembled clutch. It should be fairly obvious. Use your alignment tool, **Figure 7-35**. It will hold the disc in place and keep the disc hub aligned with the pilot bearing. This way, the input shaft will go in smoothly when you attempt to reinstall it.



Caution: When handling clutch parts, make sure your hands are clean. It is important that no oil or grease contact the clutch disc.

Match holes in the assembly to flywheel dowels, where applicable. Otherwise, align punch marks that you made during removal. Some pressure plate assemblies will be aligned through offset bolt holes. If none of these reference marks are available, turn the pressure plate assembly on the alignment tool and align bolt holes with the nearest threaded holes in the flywheel.

3. Begin threading in the clutch cover attaching bolts. Install two directly opposite each other, finger-tightening them. The clutch will now support itself. Thread in and finger-tighten the remaining bolts, making sure all bolts are started properly.



Caution: The bolts used to hold the pressure plate assembly to the flywheel are high-strength bolts. Do not use low-tension “hardware-store” replacements, as they will probably break and cause a clutch explosion.

Finish tightening the clutch cover attaching bolts by torquing them down gradually in a crisscross pattern. Make sure the pilot shaft does not sag as you tighten the bolts. Putting a slight upward force on the pilot shaft will help to retain the alignment of the clutch disc. Finish tightening the bolts to the proper torque given by the manufacturer. Once the bolts are tightened, make sure the clutch pilot shaft slides in and out freely. See **Figure 7-36**.

4. If so equipped, lubricate the seat of the clutch fork ball stud in the clutch housing. Use high-temperature grease. Install the spring clip in the fork. Force the ball stud into the fork recess so that it is engaged by the clip. If the clutch fork is the shaft type, assemble by passing the release shaft through the clutch housing and clutch fork. Lubricate the parts as necessary and lock them in place with the retaining E-clip. If lock bolts are used, be sure to torque them properly.

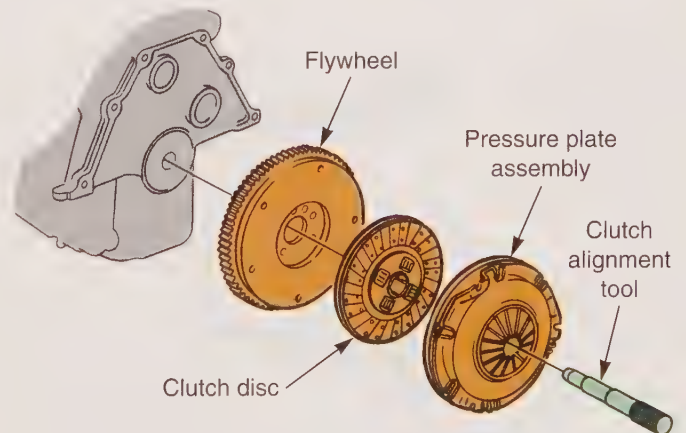


Figure 7-35. Study the relative position of the clutch parts and the clutch pilot shaft. Use of a clutch pilot shaft will make transmission reinstallation much easier. (General Motors)

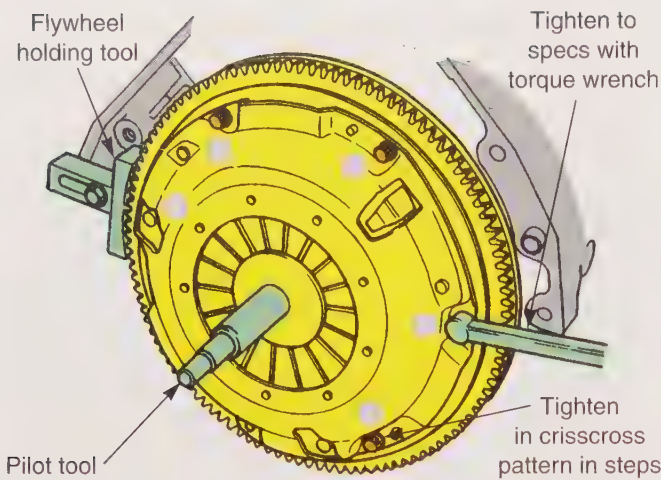


Figure 7-36. The clutch cover attaching bolts should be turned down gradually in a crisscross pattern. Push up lightly on the pilot shaft during tightening. This will ensure the disc holds its alignment. Bolts should be torqued to specifications. Once the bolts are tight, remove the alignment tool. Try sliding it in and out a few times to see that it does not bind. If it does, the transmission will be difficult to install. (Toyota)

5. Pack the inside of the throwout bearing collar with high-temperature grease. Typically, collars have an outer groove for the clutch fork. The groove should be lightly coated with grease. Refer to **Figure 7-37**.

Install the throwout bearing assembly on the fork. Use clips or retaining springs to secure the bearing to the fork. In cases where the clutch and transmission housings are one, it will be necessary to slide the bearing assembly onto the hub of the front bearing retainer first. See **Figure 7-38**.

6. If the clutch housing was removed, install it now. (A clutch housing that is integral with the transmission case is installed with the transmission.) Before installation, check for dirt or paint that could throw the housing out of alignment. As you tighten the clutch

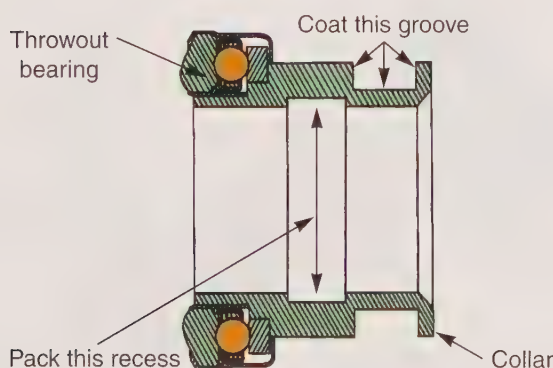


Figure 7-37. If the throwout bearing is not lubricated properly, it will bind on the hub of the transmission's front bearing retainer, or it will wear rapidly. Apply the proper type of grease to the places shown. (Chrysler)

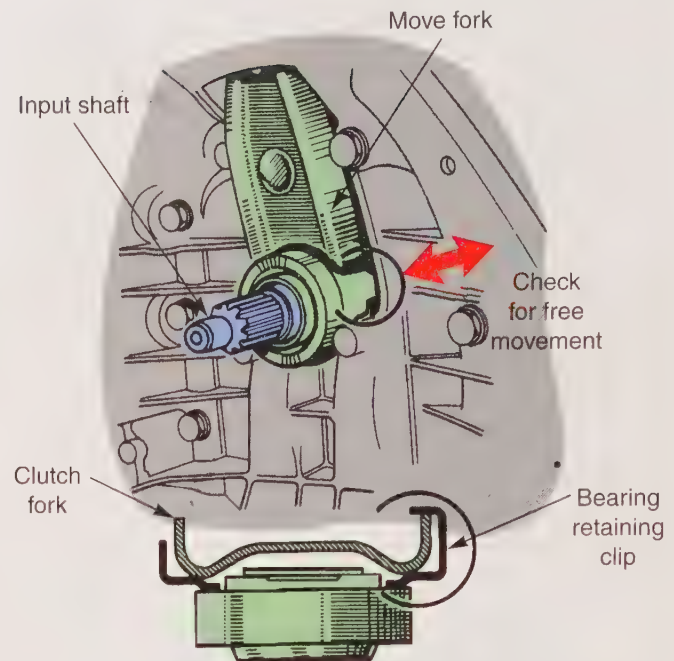


Figure 7-38. In this design, the bellhousing is an integral part of the transmission housing. The throwout bearing is placed on the front bearing retainer hub. The clutch fork is installed, and then, the bearing is secured to the clutch fork. Once assembled, the clutch fork and bearing are checked for smooth operation. Note how the bearing attaches to the clutch fork in this design variation. (Chrysler)

housing attaching bolts, make sure wires or other vehicle components do not get pinched between the housing and the engine block. Tighten the bolts in a crisscross pattern and torque them to the manufacturer's specifications.

7. Using a transmission jack, install the transmission as outlined in Chapter 9, sliding the input shaft into engagement with the throwout bearing (where clutch housing is separate), clutch disc splines, and pilot bearing. To align the input shaft and clutch disc splines, use the transmission output shaft to turn the input shaft. It may be necessary to slightly shift or wiggle the transmission to get the input shaft through the clutch disc and into the pilot bearing. If the pilot shaft was used properly, the input shaft should enter the clutch assembly without too much difficulty.



Caution: If the transmission shows any sign of oil leakage through the front bearing retainer, correct the leak before installing the transmission.

If the clutch housing is part of the transmission, bolt the unit to the back of the engine. If the clutch housing is separate, bolt the transmission case to the housing. Start the attaching bolts as soon as the input shaft is slid into place and the mating housing

surfaces are flush. This will keep the transmission from hanging and damaging the clutch hub splines or the input shaft.



Caution: Do *not* use the bellhousing or transmission case attaching bolts to try to draw in a binding transmission. This could bend the clutch disc hub or break the bellhousing or transmission case ears. Also, the transmission input shaft could damage the pilot bearing. If the clutch and pilot bearing are installed correctly, the transmission should slide fully into place by hand.

8. Reconnect the pushrod or cable and return spring connected to the clutch fork. Then, adjust, repair, or replace the linkage as outlined earlier in this chapter. Install any other parts, such as the speedometer cable, shift linkage, or connector wires.
9. Reinstall the rear drive shaft assembly as detailed in Chapter 13. If the vehicle has a front drive shaft, install it now. After the drive shaft or shafts are installed, ensure all other drive train connections are made.
10. Check the transmission lubricant and add fluid, if necessary. Reconnect the battery negative cable. Lower the vehicle and perform a road test. During the road test, make sure there is no slippage, the clutch engages and disengages smoothly, and the free play is correct. Operate the clutch at least 25 times to properly seat the clutch mating surfaces. Do not over-heat the clutch during this time.

Front-Engine, Front-Wheel Drive

With a few exceptions, the general clutch installation procedure for front-engine, front-wheel drive vehicles duplicates clutch installation for front-engine, rear-wheel drive vehicles. Drive axles are replaced instead of the drive shaft assembly. Reinstalling the several variations of front drive axles is covered in detail in Chapter 15. Also, in the previous section, substitute references to the transmission with transaxle. Installing the transaxle is covered in detail in Chapter 11. On vehicles requiring that the engine also be removed for clutch replacement, refer to the manufacturer's service manual.

Summary

Clutches can develop problems for many reasons. It is normal for a clutch to wear out after 50,000 miles (80,000 km). If a clutch wears out sooner, there may be another problem that caused premature clutch failure. The most common cause of early clutch failure is driver abuse.

Clutch problems can be divided into different groups. The most common clutch problem is slippage. Slippage

occurs when the clutch is engaged but does not transmit all of the engine power. Slippage can be caused by a worn-out clutch, improper linkage adjustments, or oil on the clutch facings. Less common causes are a warped flywheel, clutch disc, or pressure plate, or worn pressure plate apply springs. A slipping clutch should be fixed before excess heat ruins other clutch parts.

Clutch vibration can be caused by loose or unbalanced clutch parts. Loose parts usually also cause noise. Sometimes, what appears to be a clutch vibration is caused by loose engine mounts, loose clutch mounting bolts, or excessive crankshaft endplay.

Clutch noises are often caused by defective bearings. The defective bearing can be isolated by operating the clutch pedal. Depending on clutch pedal position, the pilot bearing, throwout bearing, or transmission front bearing can be at fault. Rattles and knocking noises are almost always caused by loose parts.

Clutch grabbing is usually caused by oil on the clutch facings. Other possible causes are glazed clutch facings or wear and misalignment of the throwout bearing assembly or clutch fork.

Clutch chatter is similar to grabbing, but it is heard more than felt. It can be caused by some of the same defects that cause grabbing. Sometimes chatter is caused by a buildup of clutch dust on the friction facings.

A pedal that is hard to push may be caused by a binding condition in the linkage or a throwout bearing that is sticking on the front bearing retainer hub. A new pressure plate assembly with excessively stiff springs may have been installed.

A clutch that does not release may have a defect in the linkage. Rod-and-lever linkages or cable linkages may be broken or disconnected. A hydraulic linkage may be out of fluid. If the linkage checks out, the problem is inside the clutch assembly. In some cases, the clutch disc may have welded itself to the flywheel or pressure plate.

All types of clutch linkage have some provision for adjusting the free play. Free play is measured at the clutch pedal. The usual free play measurement is between 1" and 1.5" (25 mm and 38 mm).

The clutch linkage may need lubrication or repair. Rod-and-lever linkages may require new bushings or realignment of linkage parts. Cable linkages may have problems due to a corroded or kinked cable. The cable must usually be replaced.

Hydraulic linkages can leak, or the hydraulic lines can be kinked or swelled shut. Leaks can be spotted by a visual examination.

Master and slave cylinders can be rebuilt if necessary. After rebuilding, or whenever the hydraulic system has been opened, air must be removed from the system. The process of removing air is called bleeding.

To remove the clutch from a vehicle, other components must be removed. In most cases, the drive shaft assembly or drive axles must be disconnected from the vehicle. The transmission and clutch housing are then removed to reach the clutch assembly.

To remove the clutch assembly, the clutch cover attaching bolts are removed from the flywheel. Then, the pressure plate assembly and clutch disc are removed from the flywheel.

The flywheel and pilot bearing should be checked for defects. A worn or damaged pilot bearing should be replaced. An overheated or warped flywheel can be resurfaced by a machine shop. The flywheel ring gear teeth should be checked for damage. A damaged ring gear can be removed. The replacement ring gear is installed by heating it and placing it over the flywheel.

The clutch disc is almost always replaced during a clutch teardown. The disc can be checked to determine the cause of failure. This may help avoid a similar clutch failure in the future.

Always check the new disc to make sure it is the proper replacement. Many clutch problems after overhaul are caused by using the improper clutch disc.

The pressure plate assembly is usually replaced as part of a clutch overhaul. Some assemblies can be rebuilt. The rebuilding process requires the use of a press.

The throwout bearing should be checked for roughness and lack of grease. Always replace a throwout bearing that shows any sign of defects. The throwout bearing can be pressed from its collar, and a new bearing can be installed. The clutch fork should be checked for wear. Worn forks should be replaced.

Clutch housings do not wear out, but they should be checked for cracks and warping. The housing may contain a ball stud for the clutch fork. The stud should be checked for wear and replaced if necessary.

When reassembling the clutch, always make sure your hands are free from oil. Oil or grease on the clutch disc will cause grabbing or slippage. A pilot shaft should be used to ensure the disc hub splines and pilot hole line up closely. If proper alignment is not obtained, the transmission will be difficult to install. The clutch cover attaching bolts should always be tightened with the pilot shaft in place.

After the clutch and other drive train parts are reinstalled, the clutch pedal free play should be adjusted to specifications. Road test the vehicle as the final step.

Review Questions—Chapter 7

Answer the following questions using the information provided in this chapter.

1. Explain what the phrase *riding the clutch* means. What effect can it have on the clutch over time?
2. Which of the following items concerning the phrase *dumping the clutch* is *not* true?
 - (A) Pressure plate apply springs engage gradually.
 - (B) Means increasing engine speed and then suddenly releasing the clutch pedal.
 - (C) Causes instant heat buildup on clutch disc facings and places tremendous stress on the drive train.
 - (D) Is a form of clutch abuse.

3. Vibration that occurs when the clutch is being engaged or disengaged is called ____.
4. A deep knocking noise that is similar to an engine main or rod bearing knock is an indication of _____.
 - (A) defective bearings
 - (B) a loose clutch fork
 - (C) weak retracting or cushion springs
 - (D) loose flywheel attaching bolts
5. Clutch adjustment involves _____.
 - (A) resurfacing the flywheel
 - (B) rebuilding the pressure plate assembly
 - (C) setting clutch free play
 - (D) All of the above.
6. Why should you not let a transmission hang after removing its mounts?
7. Briefly cite two methods that may be used to remove a pilot bearing from the crankshaft bore.
8. The flywheel face and pressure plate should be cleaned with a(n) _____ cleaner.
9. When inspecting a flywheel, what trouble signs should you look for?
10. Briefly summarize typical steps involved in the clutch reassembly process for a front-engine, rear-wheel drive vehicle.

ASE-Type Questions—Chapter 7

1. Each of the following operator actions can cause early clutch failure *except*:
 - (A) riding the clutch pedal.
 - (B) disengaging the clutch when decelerating.
 - (C) dumping the clutch.
 - (D) overloading the vehicle.
2. Technician A says that light clutch drag can cause gear clashing. Technician B says that clutch disc spindown can be mistaken for clutch drag. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
3. Technician A says that some clutch slippage is necessary for smooth shifts. Technician B says that an oil-soaked clutch disc will slip, even if it is not worn. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

4. Each of the following can cause clutch slippage *except*:
 - (A) excessive pressure plate apply spring pressure.
 - (B) warped flywheel or pressure plate surfaces.
 - (C) worn clutch disc.
 - (D) misadjusted linkage.
5. Technician A says that clutch grabbing and clutch chatter are the same condition. Technician B says that clutch vibration or chatter could be caused by broken engine or transmission mounts. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
6. If a noise is heard when the clutch pedal is completely released (up position) with the engine running, which of the following bearings is probably defective?
 - (A) Engine rear main bearing.
 - (B) Clutch pilot bearing.
 - (C) Throwout bearing.
 - (D) Transmission front bearing.
7. Technician A says that automatic transmission fluid can be used to refill a hydraulic clutch linkage reservoir. Technician B says that kinked clutch linkage cable can be lubricated to restore normal operation. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
8. Each of the following is caused by improper clutch adjustment *except*:
 - (A) clutch drag.
 - (B) clutch slippage.
 - (C) grabbing clutch.
 - (D) throwout bearing wear.
9. Technician A says that a badly slipping clutch usually cannot be fixed by adjusting the linkage. Technician B says that free play at the clutch pedal should be measured before attempting to adjust the clutch linkage. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
10. Opening the slave cylinder bleeder valve while pressing on the clutch pedal will cause the pedal to _____.
 - (A) slowly rise
 - (B) become hard to push
 - (C) go to the floor
 - (D) lock up
11. A pilot shaft is used to align the pilot bearing and the _____.
 - (A) pressure plate
 - (B) clutch disc
 - (C) input shaft
 - (D) throwout bearing
12. Technician A says that one should never work under a vehicle that is supported only by a hydraulic jack. Technician B says that jack stands should always be placed under a vehicle that has been raised on a hoist. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
13. Technician A says that pilot bearings should be carefully checked once the clutch is removed. Technician B says that the flywheel should not be removed unless it is damaged or needs resurfacing. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
14. A flywheel has deep scoring and cracks. Technician A says that any amount of metal can be cut from the flywheel to fix this condition. Technician B says that the flywheel can be lightly sanded and reused. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
15. Technician A says that a clutch disc should be reused unless wear or damage is severe. Technician B says that all replacement clutch parts should be carefully compared to the old parts to help ensure they will work properly. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
16. Technician A says that a pressure plate must apply evenly to prevent clutch grabbing. Technician B says that the throwout bearing should be replaced if it shows any signs of wear or damage. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

17. A car has a slipping clutch. The car will still move, but the engine races when accelerating. Technician A says to pull the transmission and replace the clutch. Technician B says to adjust the clutch linkage first. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
18. A car shudders when accelerating from a standstill as the clutch pedal is released. Technician A says to check for loose, softened, or broken motor mounts. Technician B says to check the clutch and flywheel friction surfaces for problems. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
19. A clutch makes a grinding sound as the clutch pedal is depressed and the engine is running. Each of the following could cause the problem, *except*:
- (A) misadjusted clutch linkage.
 - (B) oil or grease on the clutch.
 - (C) warped clutch disc.
 - (D) warped pressure plate.
20. A driver complains that the clutch is not working properly. The car is equipped with a hydraulic linkage. An inspection shows that the slave cylinder is not responding to pedal action. Fluid level is all right. Technician A says to try bleeding the hydraulic system first. Technician B says to replace the seals in the system first. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.



Chapter 8

Manual Transmission Construction and Operation

After studying this chapter, you will be able to:

- ☐ Explain the purpose of the manual transmission.
- ☐ Describe how a vehicle with a manual transmission is operated.
- ☐ Identify the major parts of a manual transmission.
- ☐ Discuss the purpose of each major part of a manual transmission.
- ☐ Explain the interactions of major manual transmission components.
- ☐ Describe how the major parts of a manual transmission are constructed.
- ☐ Explain the operation of a synchronizer.
- ☐ Diagram power flow through a typical manual transmission.
- ☐ Compare manual transmission designs.

Technical Terms

Gearshift lever	Clutch shaft	Inner hub
Upshifting	Countershaft	Outer sleeve
Downshifting	Manual transmission output shaft	Insert
Manual transmission shaft	Rear bearing	Insert spring
Transmission gear	Reverse idler shaft	Blocking ring
Synchronizer	Main drive gear	External shift linkage
Shift fork	Countershaft gear	External floor-shift linkage
Manual transmission shift linkage	Constant-mesh transmission	Internal shift linkage
Manual transmission case	Mainshaft gear	4-speed transmission
Extension housing	Synchromesh transmission	5-speed transmission
Manual transmission input shaft	Block synchronizer	6-speed transmission

Introduction

This chapter explains the construction and operation of manual transmissions used on rear-wheel drive vehicles. At one time, such transmissions were the only kind used in passenger cars. Today, automatic transmissions and manual and automatic transaxles are installed in many vehicles. Although manual transmissions are installed in a smaller percentage of vehicles, you must still be knowledgeable about their construction and operation.

Manual transaxles are similar in design and operation to manual transmissions, and many of the same principles apply.

Purpose of the Manual Transmission

The manual transmission multiplies engine torque or reduces engine rpm to match varying forward operating conditions. The transmission uses different gear ratios to achieve these results. (Review Chapter 4 for previous discussions of gear ratio.)

The manual transmission also provides a way to back up a vehicle. Transmissions use idler gears—gears located between drive and driven gears—for this purpose. Idler gears cause the transmission output shaft to rotate in the opposite direction of the input shaft. In this way, the idler gears allow a vehicle to be reversed. Idler gears do not change the gear ratio. (Review Chapter 4 for previous discussion on idler gears.)

Transmissions make the most of engine torque. Engines provide relatively little torque at a low rpm. Without a transmission, high engine rpm would be needed to provide enough torque to move the car from rest, and initial acceleration would be jerky and unacceptable. In a moving vehicle, the internal combustion engine develops maximum torque over only a very narrow rpm range. This narrow range occurs at relatively high engine speeds—several thousand revolutions per minute. The transmission is needed to operate the vehicle in this range under many speed and load conditions.

To use available engine torque in the most efficient manner, transmissions use several different gear ratios—first gear, second gear, third gear, and such. The lower transmission gears multiply (increase) torque while they reduce speed at the gearbox output. As vehicle speed increases, less torque multiplication is needed. A higher gear having less gear reduction is selected. Output shaft speed increases as a result, allowing engine rpm to be reduced for maximum fuel economy. (Review Chapter 4 for previous discussion on gears ratio.)

At highway, or cruising, speeds, torque multiplication is not a requirement, and direct drive is selected. A direct drive gear provides no gear reduction. Transmission output shaft speed again increases. Engine speed may be reduced

to operate within its maximum power range again. Some vehicles have one or more overdrive gears for highway travel. Overdrive gears have a gear ratio of less than one and allow the engine to run even slower and use less fuel.

Operating the Manual Transmission

In a manual transmission, such as the one shown in **Figure 8-1**, the driver selects the gears. First, the driver depresses the clutch pedal to disengage the engine from the transmission. Then, the driver moves the hand-operated transmission **gearshift lever** to select the proper gear. After the gear is selected, the driver carefully releases the clutch pedal while depressing the throttle pedal. This action smoothly couples the power between the engine and transmission. The vehicle is then in gear, and power is transmitted to the rear wheels.

In the accelerating mode, as the vehicle gains speed, the gearshift lever is moved to the next higher gear. This operation, called **upshifting**, brings the vehicle back into its peak operating range for higher speeds. Before moving the lever, the clutch pedal must be depressed and, at the same time, the throttle pedal let up. After the gearshift lever is moved, the clutch pedal is released while the throttle pedal is pushed down again.

In the decelerating mode, the same basic operation applies; however, the gearshift lever is moved into lower gears. This operation, called **downshifting**, brings the vehicle back into the peak operating range for lower speeds. In general, lower gears are used when the load is heavy or when vehicle speed is low. If an increased load, such as a hill, is encountered, the driver may downshift from high gear, for example, down to third gear or second gear.

When the vehicle is at a stop, the clutch pedal can be held down or the gearshift lever can be moved to the Neutral (no gear) position. Either action interrupts the power flow to the drive wheels.

This summarizes the basic external operation of the manual transmission. Once the driver learns to coordinate the movements of the gearshift lever, the clutch pedal, and the throttle pedal, manual transmission operation becomes an unconscious effort.

Construction and Internal Operation

To prepare for more specific details of transmission construction and operation, refer back to **Figure 8-1** and study the parts of the transmission. Learn to identify and locate the fundamental components. These components are presented in detail in this section:

- ❑ **Manual transmission shafts**—support gears and directly or indirectly transfer rotation from the clutch disc to the drive shaft assembly.
- ❑ **Transmission gears**—transmit power and provide a means of changing torque, speed, and direction at the gearbox output.

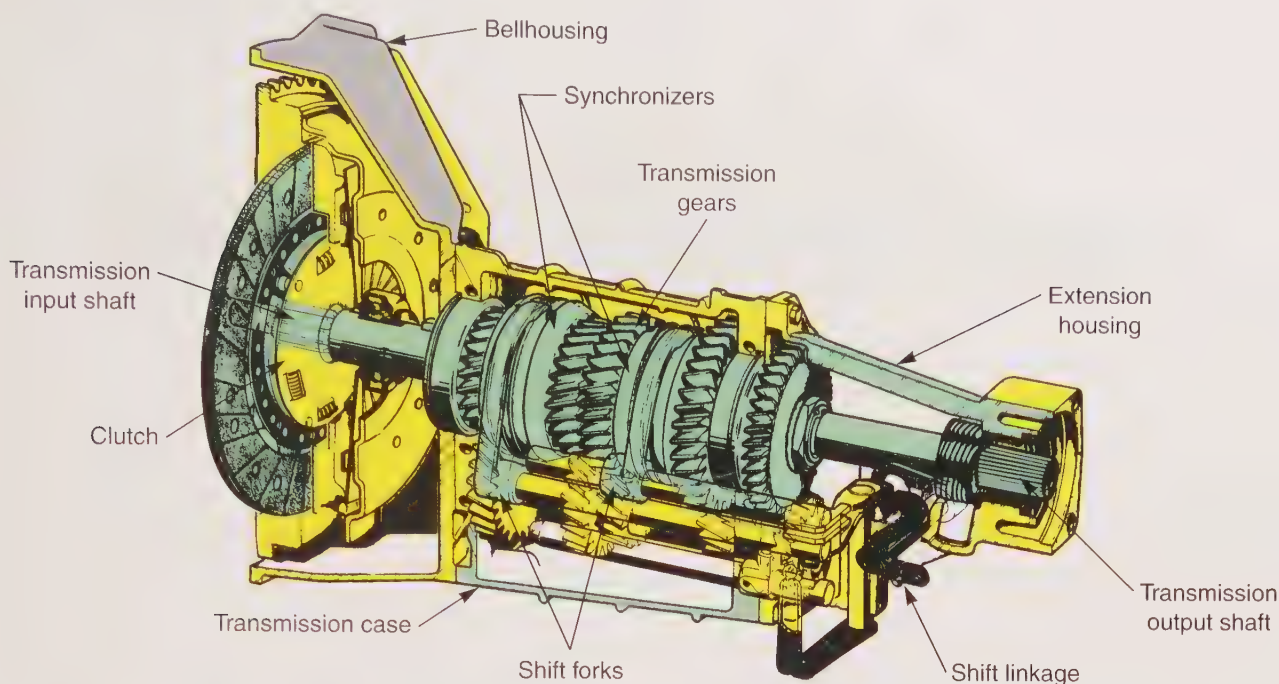


Figure 8-1. This cutaway shows parts of a typical rear-wheel drive manual transmission. Note the position of the transmission in relation to the clutch. The output shaft turns the drive shaft. All rear-wheel drive transmissions are in this relative position—directly behind the engine and directly ahead of the drive shaft assembly. (Peugeot)

- ❑ **Synchronizers**—bring certain transmission gears to the same rotational speed as the output shaft before sliding in mesh with them to lock them to the output shaft.
- ❑ **Shift forks**—pronged units that move gears or synchronizers on their shaft for gear engagement.
- ❑ **Manual transmission shift linkage**—allows the driver to operate the shift forks.
- ❑ **Manual transmission case**—encloses transmission shafts, gears, synchronizers, shift forks, linkage, and lubricating oil. In some designs, it is combined with the clutch housing.
- ❑ **Extension housing**—encloses the tail end of the transmission output shaft, which extends from the transmission case. It also encloses part of the shift linkage.

In addition to these seven major parts, there are numerous accessory devices mounted on the transmission. Some of these devices, such as the speedometer assembly, receive their input from the transmission. These accessories will also be discussed in this section.

Manual Transmission Shafts

Transmission shafts are directly or indirectly involved in transmitting motion. A shaft may rotate to perform its function, or it can be a stationary support for a moving gear. Transmission shafts are made from high-strength steel. They are closely machined and polished. Often, they are heat-treated to increase their strength and resistance to wear.

All rotating shafts are supported by bearings attached to the case. These shafts are machined with splines and

grooves designed to mate with other transmission parts, such as gears, bearings, and snap rings.

Nonrotating shafts are machined smooth so that the gears can rotate on them easily. They are held in place by pins or locknuts or are press fit. In some instances, the shaft is not attached to the case and can rotate in a random manner.

There are many variations of shaft design and placement in manual transmissions. **Figure 8-2** shows the four basic shafts found in all manual transmissions: the manual transmission input shaft, the countershaft, the manual transmission output shaft, and the reverse idler shaft.

Manual transmission input shaft

The **manual transmission input shaft**, splined to the clutch disc, delivers power to the transmission. Sometimes called the **clutch shaft**, this rotating shaft transfers rotation from the clutch disc to the countershaft gear. The input shaft, as described in Chapter 6, is supported on the front end by the pilot bearing. The transmission main drive gear is machined on the inner end of the shaft and contained within the transmission case. The transmission front bearing, which is held by the transmission case, supports the inner end of the input shaft.

The input shaft and front bearing are held in place by the front bearing retainer. This retainer prevents forward shaft movement. The output shaft prevents rearward movement of the input shaft. The front bearing is kept from moving by a snap ring, which holds it solidly to the case. In some instances, a snap ring is used for holding the main drive gear to the bearing to prevent lateral shaft movement.

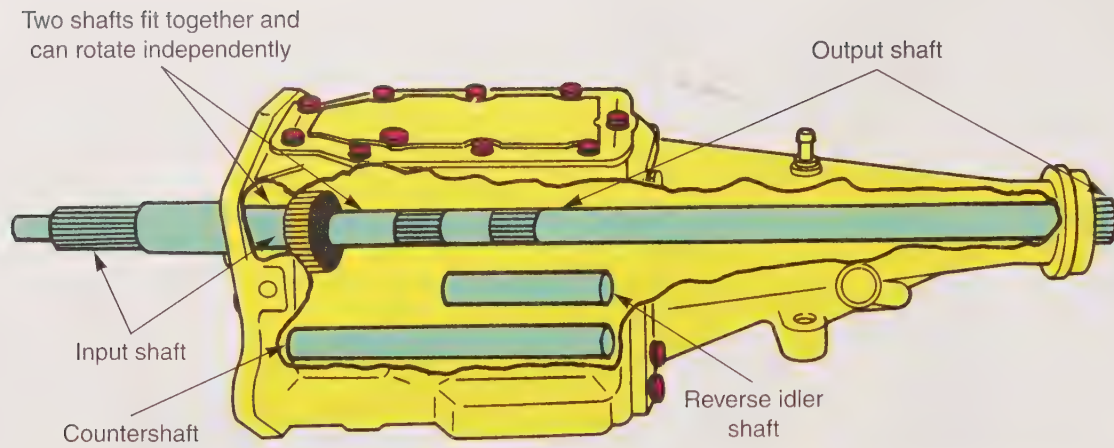


Figure 8-2. This shows the major shafts that are found in manual transmissions. Note that needle bearings are used between input and output shafts since they often rotate at different speeds.

Countershaft

The **countershaft** holds several gears of different sizes. It is the central shaft of the countershaft gear assembly. It is located below the input shaft. Normally, the countershaft does *not* turn in the transmission case. Instead, it is locked in place.

Manual transmission output shaft

The **manual transmission output shaft**, also called the **mainshaft**, is attached to the vehicle drive shaft assembly. This rotating shaft delivers power to the drive shaft assembly. This shaft holds the output gears and synchronizers.

The front end of the output shaft fits into the end of the input shaft, where it rides on needle bearings, sometimes called the output shaft pilot needle bearings. The output shaft and the input shaft are aligned, so they look like one shaft. The two shafts, however, are free to rotate separately, except when in direct drive, where they are locked together and rotate at the same speed. Sometimes, a thrust bearing is used to control endplay between the input and output shafts.

The output shaft extends to the back of the extension housing. The rear end is splined and connects to the drive shaft assembly. The shaft is supported by one or two anti-friction bearings. Typically, the transmission **rear bearing** provides the central support for the shaft. The rear bearing is commonly held in place either by the transmission case or the front part of the extension housing; however, in some designs the rear bearing is held in the rear of the extension housing.

Reverse idler shaft

The **reverse idler shaft** is a short shaft that supports the reverse idler gear. It is normally mounted in the case about midway between the countershaft and output shaft. A key or other retainer is used to hold the reverse idler shaft so it does not turn.

Transmission Gears

Transmission gears transmit power. These are gears of different sizes that are used to obtain different gear ratios—either reducing output speed to multiply torque or increasing output speed to reduce engine rpm. In addition, certain other transmission gears are used to move a vehicle in reverse.

Transmission gears are made of high-strength steel. They are machined and then hardened by a heat-treating process. Two types of gears are commonly used in manual transmissions. Spur gears, which have straight-cut teeth, are used for gears that are only used occasionally. An example is reverse gear. Most other transmission gears are helical gears. Helical gears run more quietly and are stronger because of increased contact of the teeth, which are cut at an angle. Helical gears must be mounted with a minimum of endplay, since they tend to slide apart due to thrust forces caused by the angular tooth contact.

Transmission gears are held on transmission shafts. Transmission gears may be an integral part of the shaft or they may be splined to the shaft. Some gears rotate on the shaft. Transmission gears are classified with their associated shaft. The four types include the main drive gear, countershaft gear, mainshaft gears, and reverse idler gear. See **Figure 8-3**.

Main drive gear

The transmission input shaft and **main drive gear** are a one-piece unit, **Figure 8-4**. The shaft is splined to the clutch disc. The clutch disc turns the shaft and main drive gear whenever the clutch is engaged. When the transmission is in Neutral (clutch engaged), the input shaft turns, but the output shaft does not turn. **Figure 8-5** shows an input shaft, main drive gear, and related parts in an exploded view.

Countershaft gear

The **countershaft gear**, or **cluster gear**, as it is also called, is a series of helical gears machined out of a single piece of steel. An exploded view of a typical countershaft

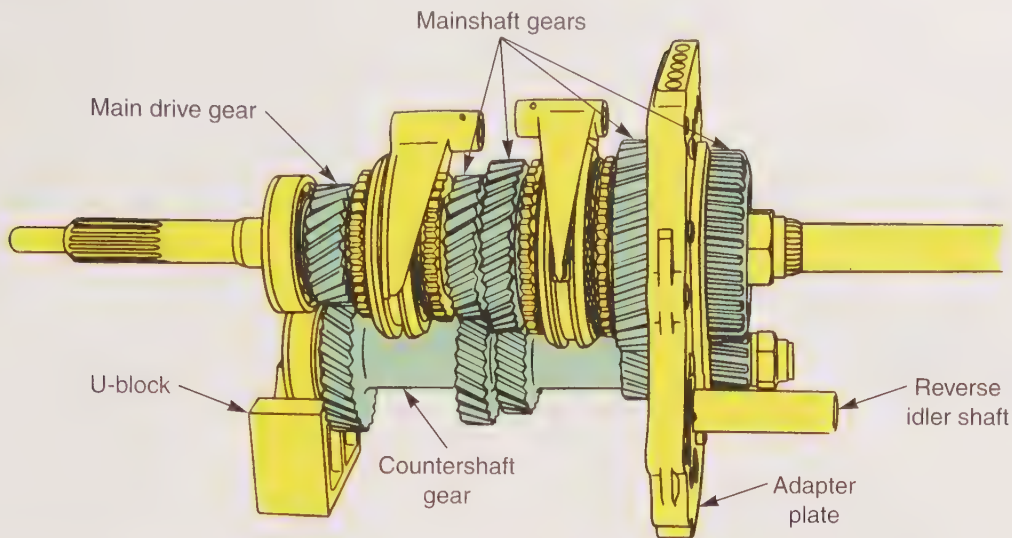


Figure 8-3. Note the typical manual transmission gears. The reverse idler gear is not shown. (General Motors)

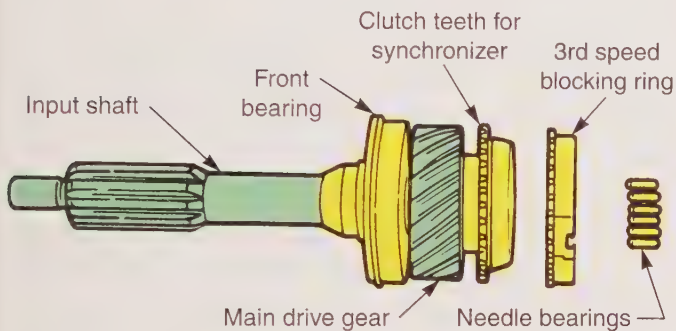


Figure 8-4. Study the typical input shaft and its integral drive gear. Most are one-piece, hardened-steel castings. The front bearing is pressed on the input shaft. It can be removed if defective. Needle bearings are placed inside the bore at the end of the input shaft. The output shaft rides on needle bearings. (General Motors)

gear assembly, which includes the gear, countershaft, and related parts, is shown in **Figure 8-6**.

The largest gear on the countershaft gear is always the countershaft driven gear, which is the forward most gear. This gear is always in mesh with the main drive gear, as shown in **Figure 8-7**. The entire countershaft gear turns whenever the main drive gear turns.

In addition to the driven gear, there is usually one gear on the gear cluster for each available reduction and overdrive ratio, plus a gear for reverse. There is no gear for direct drive (1:1 gear ratio); the countershaft gear is not used in direct drive. The cluster gear of a 5-speed transmission with overdrive, for instance, has six gears. In addition to the countershaft driven gear, it has first, second, third, overdrive, and reverse gears.

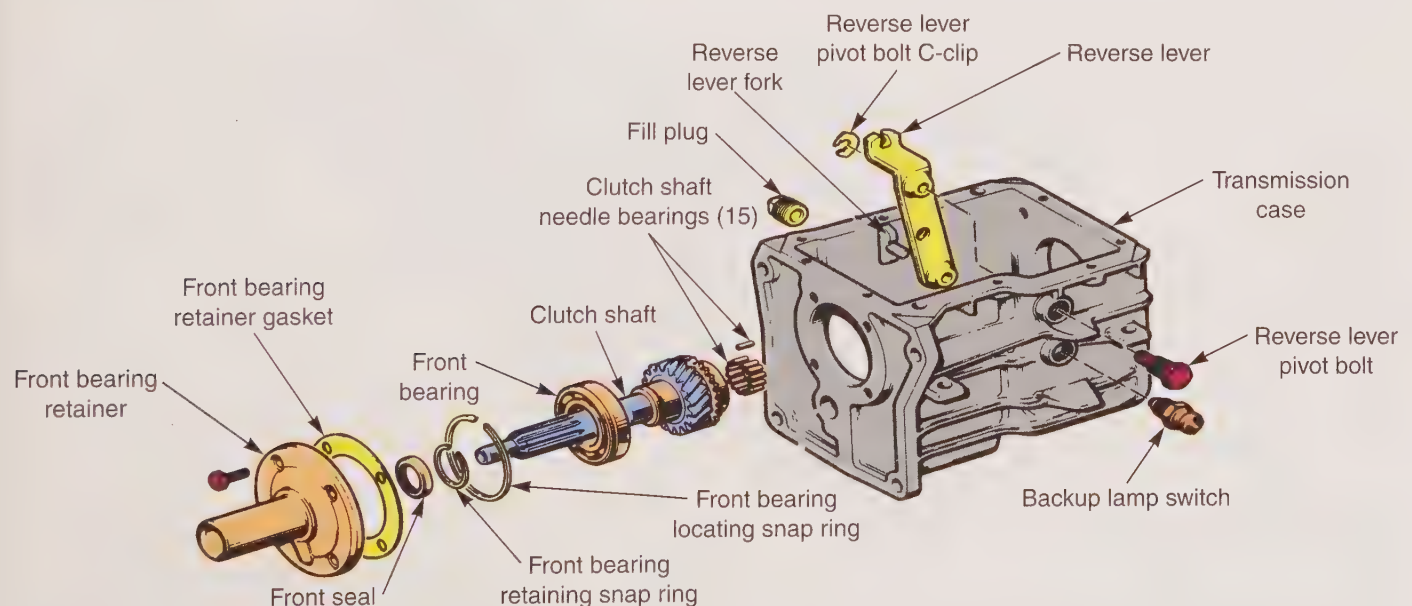


Figure 8-5. Exploded view shows the position of the input shaft and its related parts in relation to the transmission case. (Chrysler)

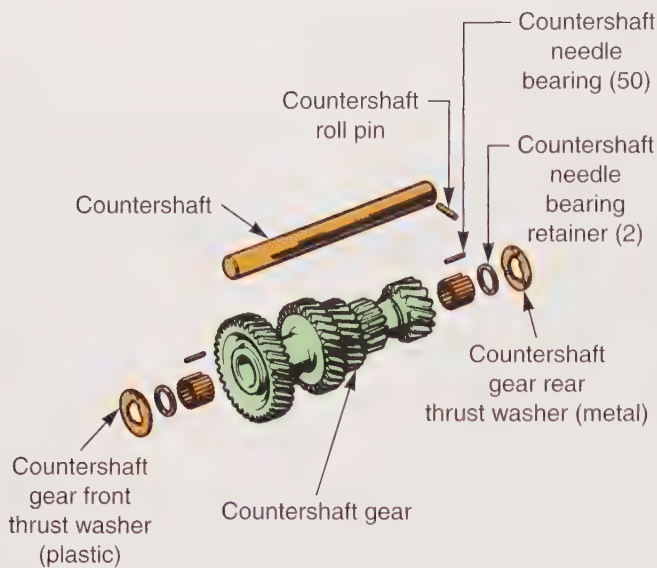


Figure 8-6. Exploded view shows the parts of the countershaft gear assembly. This shaft is locked in place by countershaft roll pin. Thrust washers control endplay in the countershaft gear. The countershaft gear rides on needle bearings. (Chrysler)

The size of the individual gears on the cluster increases with each drop in gear ratio. For example, second gear has a smaller ratio than first gear, and it is larger in size than first gear. Third gear has a smaller ratio than second gear, and it is larger than second gear.

In most designs, the countershaft gear rotates on a countershaft that is stationary. Needle bearings are used between the cluster gear and shaft to reduce wear. Needle bearings may be loose, or they may be caged. Some designs incorporate caged needle bearings because they are easier to work with. The bearings do not fall all over the bench during disassembly, and installing the bearings is also much easier.

Thrust washers placed between the ends of the assembly and the transmission case control endplay, or back-and-forth movement, of the countershaft gear. In some transmissions, the countershaft gear is supported, and endplay is controlled through the use of tapered roller bearings. **Figure 8-8** shows tapered roller bearings used on a countershaft gear.

Some gears are in constant mesh with the countershaft gear: one is the main drive gear and the other is the reverse idler gear. In modern transmissions, all forward gears of the countershaft are in constant mesh with the mainshaft gears, which are free to rotate. These are sometimes referred to as **constant-mesh transmissions**. Reverse gear may be the constant-mesh type, or it may be the type that slides in and out of engagement. In some early constant-mesh transmissions, both first and reverse used sliding gears.

Mainshaft gears

The output shaft contains the gears that provide forward speeds and reverse. **Mainshaft gears** mount over the

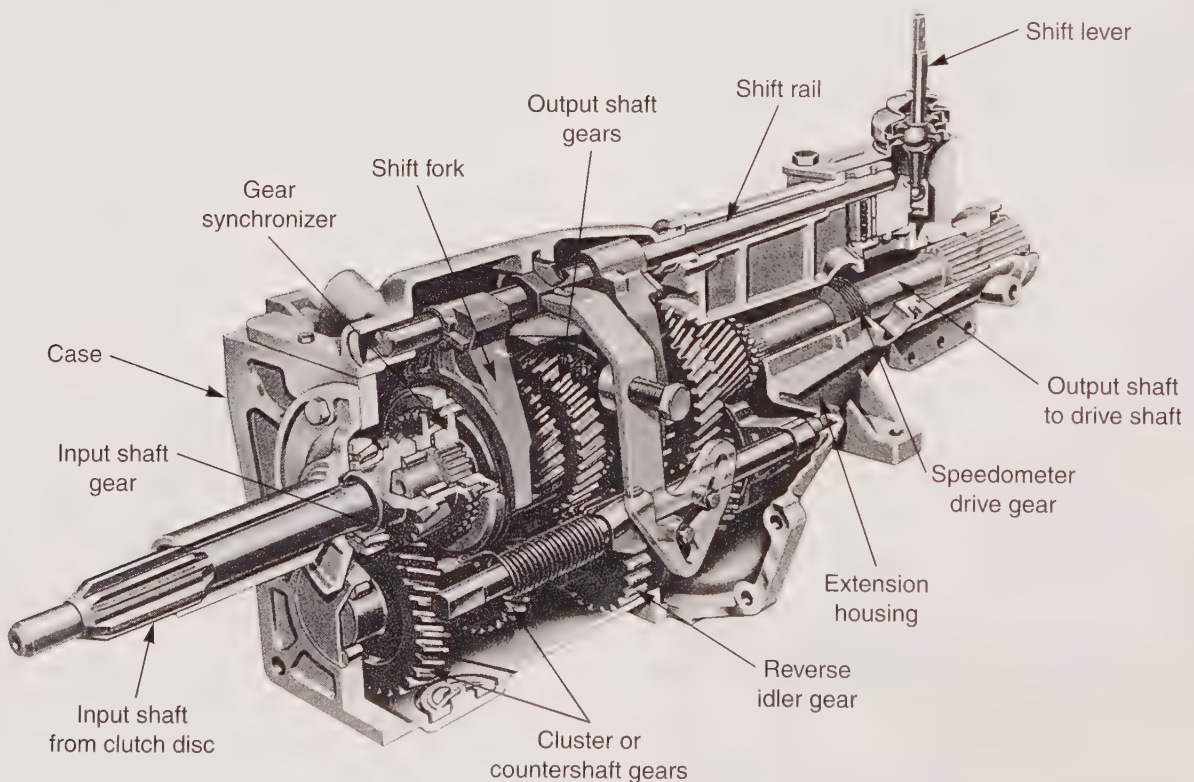


Figure 8-7. This cutaway points out the various parts of a modern 5-speed manual transmission with overdrive. Notice how the main drive gear fits into the transmission case and meshes with the countershaft gear. (Ford)

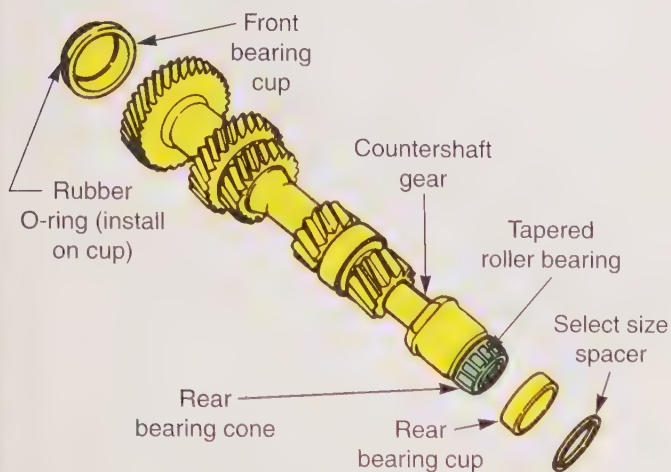


Figure 8-8. The countershaft gear sometimes gets its support from tapered roller bearings on each end. The bearings also control endplay. This design does not use a countershaft. (Chrysler)

transmission output shaft. See the mainshaft gear assembly shown in **Figure 8-9**. The mainshaft gears include one gear for each available reduction ratio and the overdrive ratio. In addition, while not the case in this particular design, there is typically a gear for reverse.

Each mainshaft gear (and the main drive gear) comprises two sets of teeth. Next to the set of large, helical teeth is a set of small, straight-cut teeth. The straight-cut teeth are called clutch teeth. Each gear has a tapered, or cone, surface next to the clutch teeth.

Typically, each mainshaft gear has a bushing pressed into its inside diameter. The bushing is a close fit with the matching machined area, or race, on the shaft. The bushing turns on the race, and the transmission lubricant reduces friction.

In modern transmissions, the gears can turn freely (and independently) on the output shaft. Each gear turns at a different speed, depending on the gear ratio between it and its mating countershaft gear. The output shaft itself will not begin to turn until one of the mainshaft gears becomes locked to the shaft. Synchronizers, which are splined to the output shaft, are the devices that lock the gears to the shaft. Normally, only one gear will be engaged, or locked to the shaft, at a time.

Reverse idler gear

The reverse idler gear is used to reverse the rotation of the output shaft for backing up the vehicle. This gear is turned by the countershaft reverse gear. It mounts on the reverse idler shaft, which is normally stationary. Refer to the reverse idler gear assembly shown in **Figure 8-10**. Needle bearings are used between the gear and shaft to reduce wear. Thrust washers, which are placed between the ends of the gear assembly and the transmission case, control endplay. The interior of the transmission case often contains a special projection to hold one end of the idler shaft.

Synchronizers

Constant-mesh manual transmissions, used on modern vehicles, make use of synchronizers. These assemblies are required for shifting from one gear to another. They permit gears to be selected without clashing, or grinding. Synchronizers do this by synchronizing (matching) the speed of mating mainshaft gears or the main drive gear to the output shaft speed before the gears engage. Gear clash makes shifting difficult and causes damage to gears and synchronizers. Through the use of synchronizers, mainshaft gears can be locked to the output shaft, or in the case of direct drive, input and output shafts can be locked together without damage.

Modern transmissions are synchronized in forward gears. Such transmissions are referred to as **sychromesh transmissions**. Reverse gear is not usually synchronized, since the vehicle should be stopped before being shifted into reverse.

When the synchronizer is away from a mainshaft gear, the gear mainshaft freewheels, or spins, on the output shaft. No power is transmitted to the output shaft. When shifting gears, the clutch is disengaged, which means the input shaft is disengaged from the engine. Shift forks slide the synchronizer against a gear, locking the gear to the synchronizer and to the output shaft. The clutch is then re-engaged, and power is sent out the transmission to the drive shaft. Synchronizer operation is described in greater detail in upcoming paragraphs.

Synchronizer construction

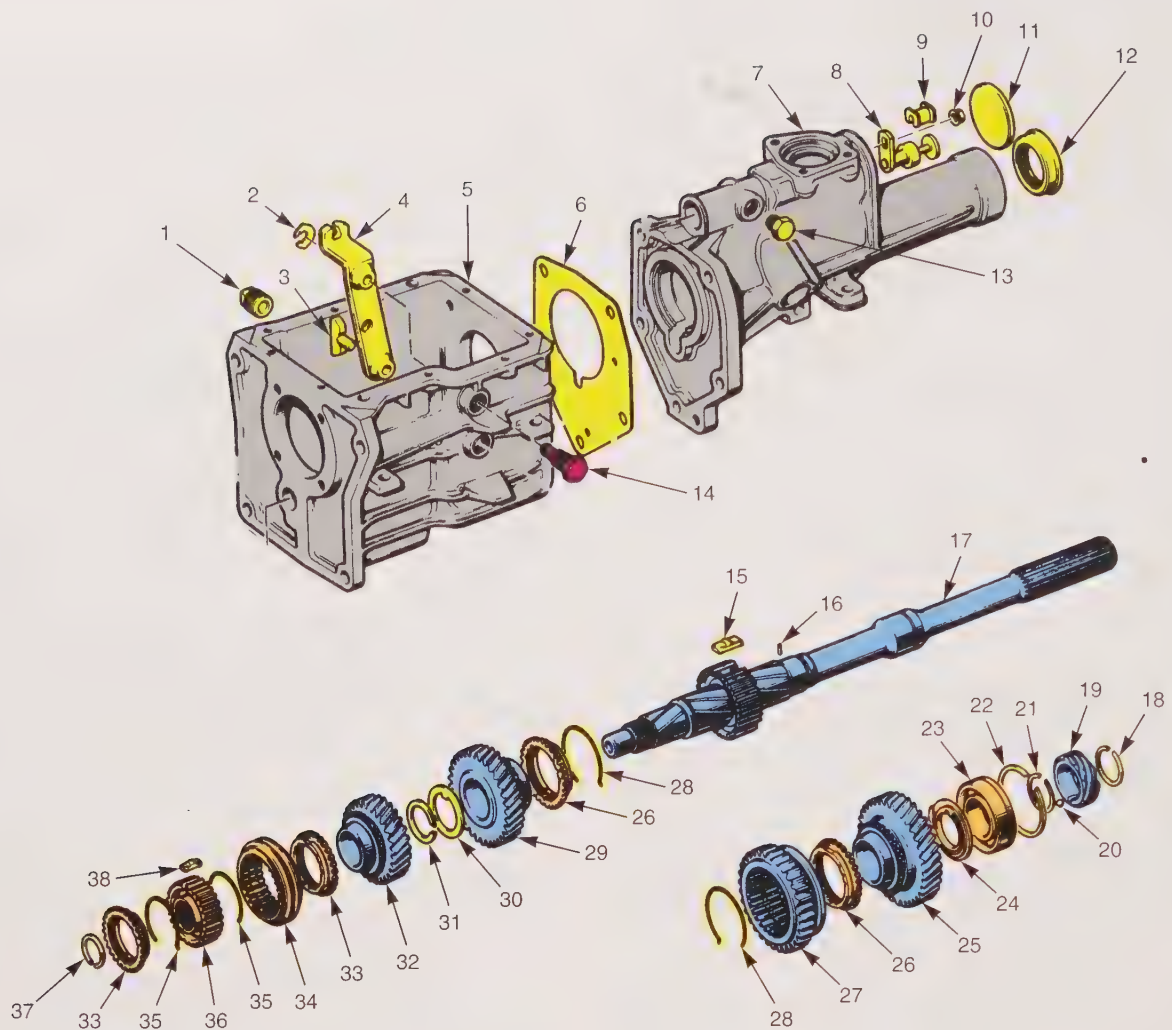
The most popular type of synchronizer for an automotive manual transmission is the **block synchronizer**. This assembly consists primarily of the following components: inner hub, outer sleeve, inserts, insert springs, and blocking rings. See **Figure 8-11**.

The **inner hub** is splined to and rotates with the output shaft. It is held in a stationary position between the transmission gears. The hub also has external splines that mate with the outer sleeve.

The **outer sleeve** has internal splines that mate with the external splines of the inner hub. The sleeve can slide back and forth along the splines of the hub. The internal splines of the outer sleeve also mate with the straight-cut teeth of the gears next to which they are mounted.

The **inserts** serve, in part, as detents. They fit into slots along the inner hub. The **insert springs** fit around the backside of the inner hub, in the recessed area. They push against the inserts, forcing the notches on the inserts into engagement with the notches in the internal splines of the sleeve. This holds and centers the sleeve on its hub. The inserts slide back and forth with the outer sleeve.

The **blocking rings** are toothed brass or copper rings. One is located between each sleeve-and-hub assembly and mainshaft gear; it is not attached to either, **Figure 8-12**. The blocking ring acts as a clutch to speed up or slow down the mating gears to match the speed of the output shaft.



- | | | |
|--|---|---|
| 1. Fill plug | 16. First gear roll pin | 29. Second gear |
| 2. Reverse lever pivot bolt C-clip | 17. Output shaft and hub assembly | 30. Second gear thrust washer (tabbed) |
| 3. Reverse lever fork | 18. Speedometer gear snap ring | 31. Second gear snap ring |
| 4. Reverse lever | 19. Speedometer gear | 32. Third gear |
| 5. Transmission case | 20. Speedometer gear drive ball | 33. Third – fourth synchronizer blocking ring (2) |
| 6. Extension housing gasket | 21. Rear bearing retaining snap ring | 34. Third – fourth synchronizer sleeve |
| 7. Extension housing | 22. Rear bearing locating snap ring | 35. Third – fourth synchronizer insert spring (2) |
| 8. Offset lever | 23. Rear bearing | 36. Third – fourth synchronizer hub |
| 9. Offset lever insert | 24. First gear thrust washer | 37. Output shaft snap ring |
| 10. Offset lever retaining nut | 25. First gear | 38. Third – fourth synchronizer insert (3) |
| 11. Access plug | 26. First – second synchronizer blocking ring (2) | |
| 12. Extension housing oil seal | 27. First – reverse sleeve and gear | |
| 13. Threaded plug | 28. First – second synchronizer insert spring (2) | |
| 14. Reverse lever pivot bolt | | |
| 15. First – second synchronizer insert (3) | | |

Figure 8-9. Exploded view shows parts of the mainshaft gear assembly. The output shaft extends back through the extension housing. (Chrysler)

The teeth on the blocking ring are situated along the outside diameter of the ring. They match the straight-cut teeth of the mating gears and mate with the internal splines of the outer sleeve, **Figure 8-13**. The inside diameter of the blocking ring is tapered. This surface fits over the cone surface on the mating gear. The tapered surface of the ring

has many small, sharp ridges, which enable the synchronizer to solidly engage the cone surface of the mating gear. Commonly, the inner (assembly) side of the blocking ring fits into the recessed region between the inner hub and the output shaft, where matching slots in the ring engage the inserts of the inner hub.

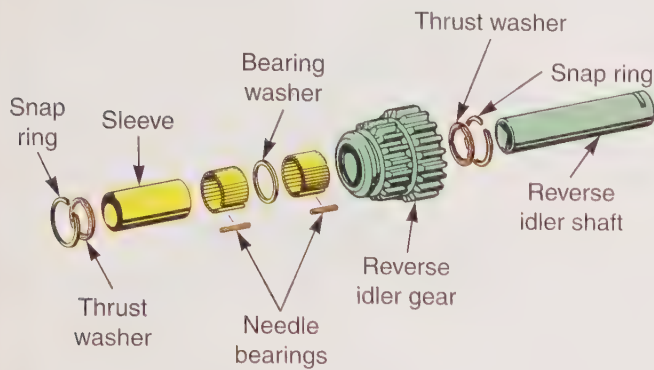


Figure 8-10. Exploded view shows the parts of the reverse idler gear assembly. The reverse idler shaft is normally locked in place. Thrust washers control endplay. (Chrysler)

The blocking ring, when fully engaged, fits between the mating gear and the outer sleeve. However, the sleeve does not move into engagement with the teeth on the gear until the ring and gear are brought to the same speed.

Synchronizer operation

Synchronizer operation is relatively simple. The driver pushes the clutch pedal to disengage the clutch and uses the gearshift lever and linkage to operate the synchronizer outer sleeve. When the outer sleeve is moved toward the gear to be engaged, the internal teeth of the sleeve mesh with the external teeth of the blocking ring. This causes the blocking ring to turn at the same speed as the sleeve, which is turning at output shaft speed. (If the blocking ring is held in place with inserts, it is already turning at sleeve speed.)

As the outer sleeve continues to move, it pushes the blocking ring into engagement with the cone surface of the mating gear. The mating gear is unloaded because no engine power is being delivered while the clutch is disengaged. Friction between the two surfaces brings the mating

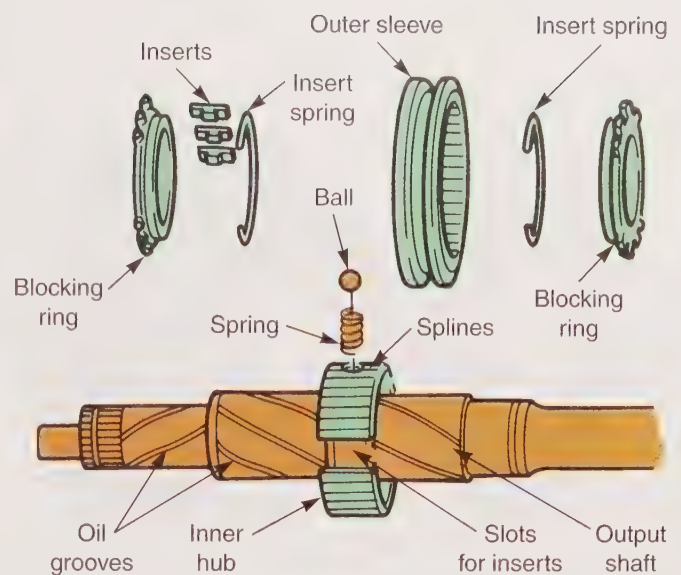
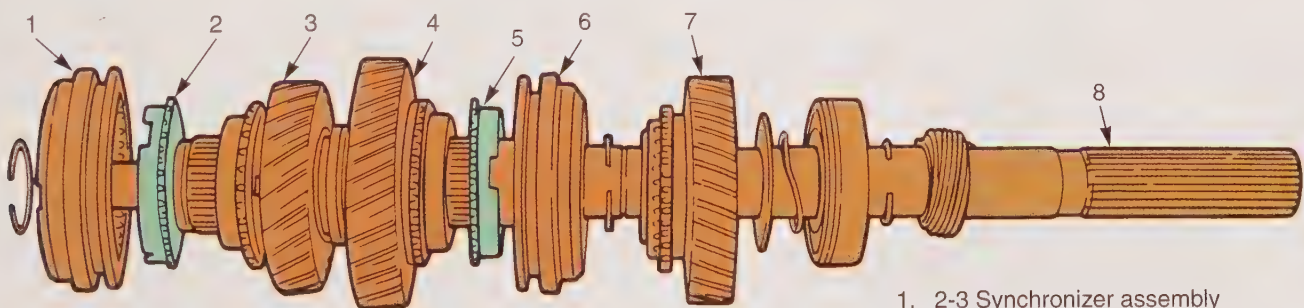


Figure 8-11. Basic synchronizer components. The inner hub is splined to the output shaft. The outer sleeve fits over the inner hub. Blocking rings allow the sleeve to slide into and mesh with the mainshaft gear without clashing. Spring-loaded inserts and ball keep the sleeve centered on the hub until the shift fork pushes the sleeve on the hub. Note that the helical lines around the output shaft are oil grooves. (General Motors)

gear to the same speed as the outer sleeve and, therefore, to the speed of the output shaft. The ring and cone surfaces become solidly engaged. The sleeve continues its forward (or rearward) movement, and it engages the mating gear without clashing. This locks gear, sleeve, hub, and output shaft together. Now, the gear is engaged with the output shaft, and the clutch pedal can be released. Power flows through the gear and on to the rear wheels.

Note that direct drive is provided by engaging the sleeve and blocking ring directly with the cone surface on the main drive gear. Also, note that some transmissions use a single sliding gear for low and reverse. The gear is free to



1. 2-3 Synchronizer assembly
2. 2nd Speed blocking ring
3. 2nd Speed gear
4. 1st Speed gear
5. 1st Speed blocking ring
6. 1st Speed synchronizer assembly
7. Reverse gear
8. Output shaft

Figure 8-12. This shows the location of the blocking rings in relation to the sleeve and hub assemblies and the mainshaft gears. Note that the parts would actually be closer together than what is shown in this somewhat exploded view. (General Motors)

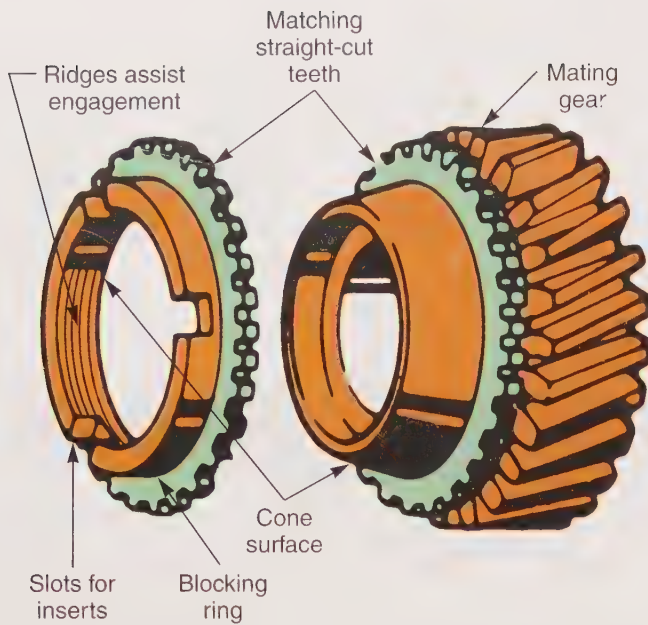


Figure 8-13. A typical blocking ring is a brass ring with external teeth, which match the straight-cut teeth of the mating gear, and a tapered surface, which mates with the tapered surface of the mating gear. Ridges in the tapered surface help the synchronizer to solidly engage the cone. (Chrysler)

slide back and forth on splines cut into the output shaft. It can be moved to mesh with the low countershaft gear or the reverse idler gear.

Shift Forks

The shift fork, operated by the transmission shift linkage, moves in a straight line to push the synchronizer sleeve into engagement with the gear. Shift fork action is illustrated in **Figure 8-14**. Shift forks are made to slip into grooves cut into the outer sleeves of the synchronizer assemblies, **Figure 8-15**. The groove allows the synchronizer assembly to turn with the shaft. The design makes it

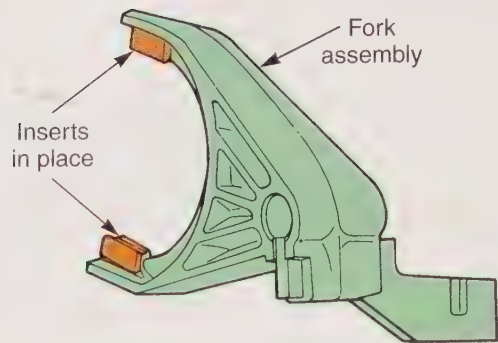


Figure 8-15. Shift forks such as these are used to move the outer sleeves of the synchronizer assemblies. (Ford)

possible for the fork to move the sleeve backward and forward, while allowing the sleeve to rotate.

Some shift forks are made of steel, cast iron, or aluminum. Aluminum shift forks sometimes have nylon inserts at the point where they contact the sleeve. This reduces wear on the fork's contact points.

Manual Transmission Shift Linkage

The driver, through a series of shafts, levers, links, and sometimes, cables, operates the shift forks. There are many ways to transfer the force of the gearshift lever to the gears. Some systems are simple, while others are more complex. Shift linkages connect the gearshift lever to the shift forks. They can be divided into two general types of systems—external and internal.

External shift linkage

External shift linkage is a system that is identified as a series of rods and levers that connect to the outside of the transmission. In addition, some later external systems use cables instead of rods. External shift linkage may be connected to the gearshift lever, which is either on the steering column or on the floor.

At the transmission case, the external shift linkage connects to the inside through shafts that pass through the side of the case. Inside, each shaft connects to a shift lever. The shaft rotates to move the lever. The lever moves forward or backward to move the shift fork. In this way, shaft rotation is converted to straight-line movement at the shift fork.

The internal shift lever usually has some type of spring-loaded detent. The detent is a holding mechanism that keeps the lever and, therefore, the fork and synchronizer sleeve in position when in Neutral or in gear. There is also a shift interlock, which ensures that each shift lever is in the Neutral position before the other shift lever can move the gears. This way, only one gear combination can be engaged at a time.

External floor-shift linkage is used on modern transmissions, **Figure 8-16**. The gearshift lever assembly mounts to the rear of the transmission, usually on the extension housing. The gearshift lever extends upward through a hole in the vehicle floor pan. This hole is sealed by a flexible

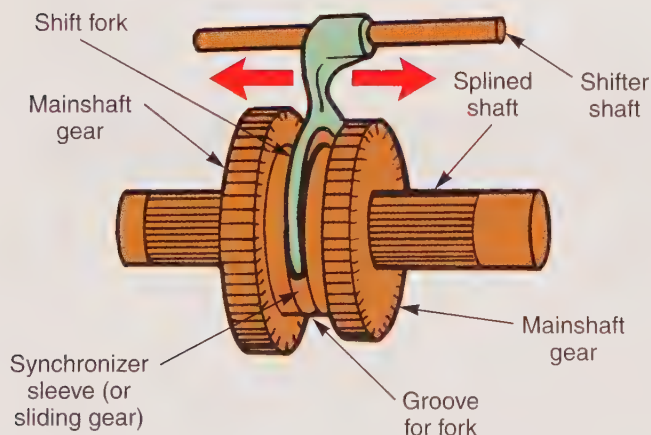


Figure 8-14. Shift forks move in a straight line to move the synchronizer sleeve (or sliding gear) in and out of engagement. The shift fork is operated by the shift linkage.

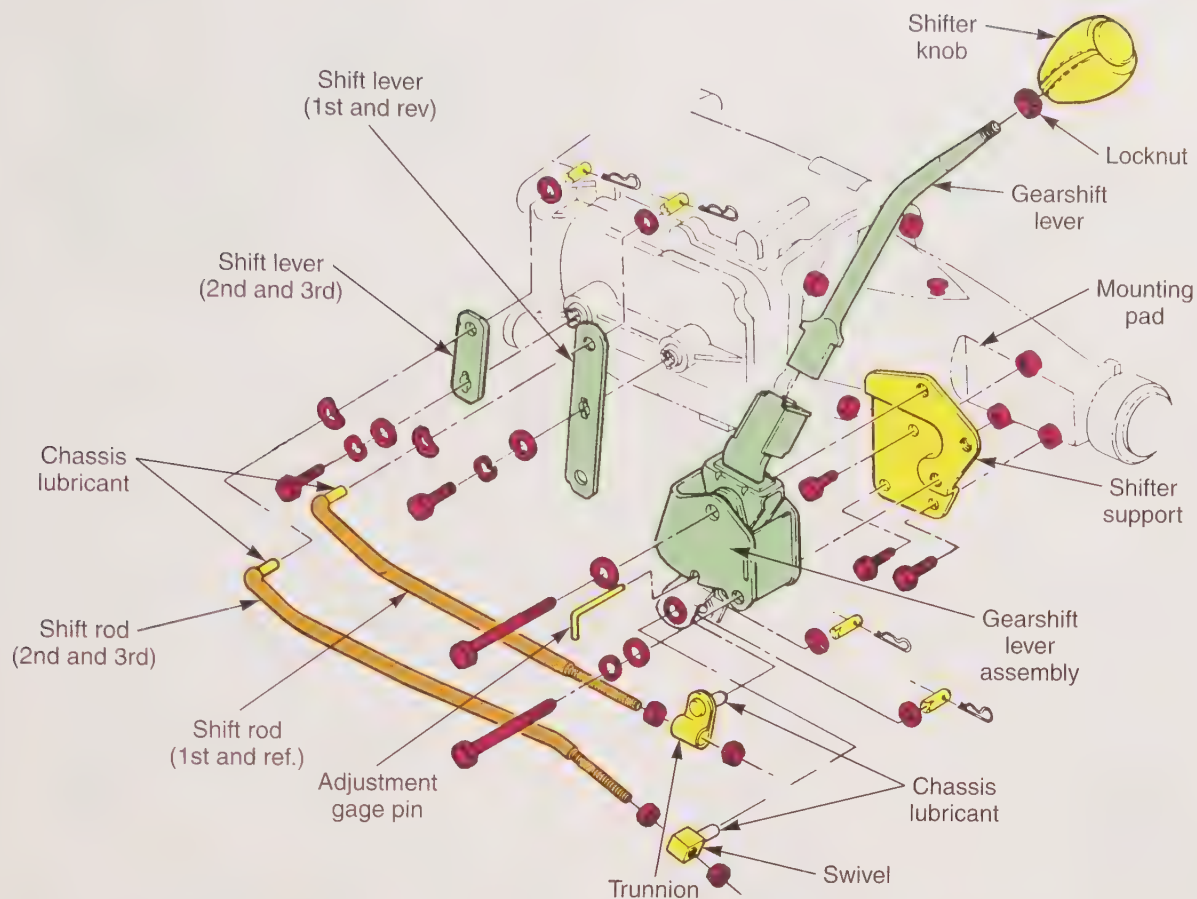


Figure 8-16. In the external floor-shift linkage, a series of levers and rods transmit motion from the gearshift lever to the transmission. (General Motors)

rubber boot, which keeps out dust and water while allowing gearshift lever movement. The gearshift lever assembly transfers gearshift lever movement to the shift rods. The shift rods operate the shift levers on the transmission case.

Linkage parts for the external floor-shift linkage are attached with cotter pins through drilled holes in the shift rods. Washers and bushings are used at linkage pivot points to reduce wear, and the linkage can be adjusted by threaded swivels on the shift rods.

Internal shift linkage

Internal shift linkage is found only on transmissions with floor-mounted gearshift levers. In many instances, the gearshift lever extends down into the extension housing. The transmission and floor pan openings are sealed with rubber boots. **Figure 8-17** is an example of such a gearshift lever.

One common type of internal shift linkage employs a single shifter shaft, or shift rail. See **Figure 8-18**. The shift forks are positioned along the shifter shaft. When a gear is selected, the lower end of the gearshift lever moves into an offset lever at the end of the shifter shaft. Further movement of the gearshift lever causes the shifter shaft to move, along with the desired shift fork. The interlock plate locks out all gears except the one selected.

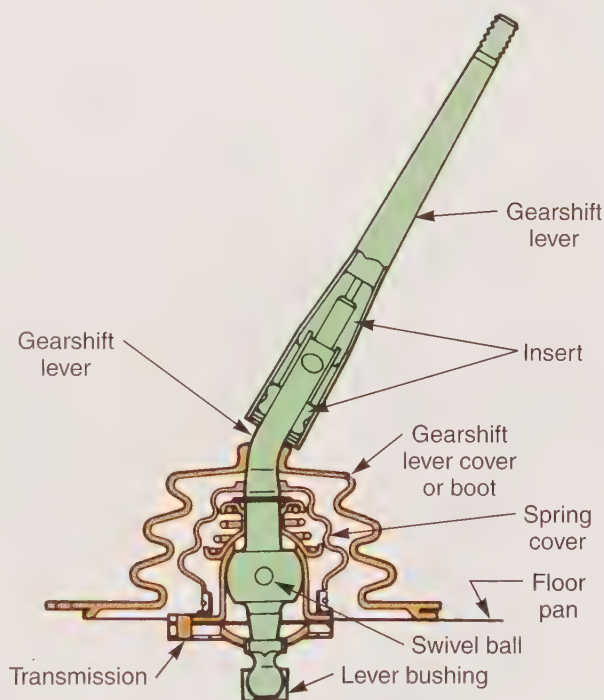


Figure 8-17. The gearshift lever of an internal shift linkage is shown here. The gearshift pivots on an internal ball to move the shift linkage. Boots at the transmission and floor pan prevent the loss of lubricant and the entry of dirt and water. (Chrysler)

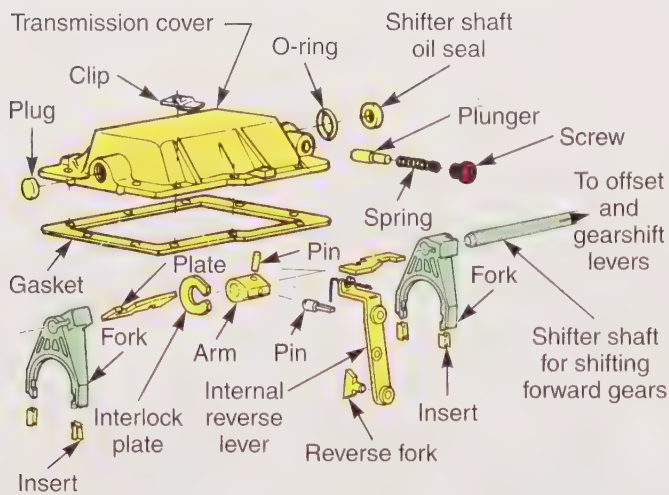


Figure 8-18. A single shifter shaft is used in some manual transmissions. Note that the shaft extends out of the transmission cover, through the oil seal, and into the extension housing. In the transmission shown, the reverse gear is operated through a separate reverse lever. (Ford)

A second type of internal shift linkage employs a series of rods, or shift rails, to operate the shift forks. See **Figure 8-19**. Many transmissions use this system. A shift fork is attached to each shift rail. In addition, the shift rails have notched units attached, directly or indirectly, to their outer ends.

When the driver shifts gears, the bottom of the gear-shift lever catches in one of the shift rail notches. As a result, the shift rail and shift fork are moved and transmission gears are changed.

Manual Transmission Case

The transmission case supports the transmission shafts and forms a reservoir for lubricant. It is the main housing, or structure, of the transmission. The front of the case attaches to the clutch housing. In some designs, the clutch housing and case are a single integral casting. In other designs, the case bolts to the back of the clutch housing, **Figure 8-20**. The transmission case is also the attaching

- | | |
|-------------------------------|--------------------------------|
| 1. Reverse fork and shift arm | 11. Lock ball, spring and plug |
| 2. 1-2 Shift fork | 12. Shift arm |
| 3. 3-4 Shift fork | 13. Set bolt and lock plate |
| 4. Lock ball, spring and plug | 14. Shift lever shaft |
| 5. Bracket bolt | 15. Shift plug |
| 6. No. 3 shift rail | 16. Reverse pin |
| 7. No. 1 shift rail | 17. Retaining pin and plug |
| 8. C-ring | 18. No. 5 shift rail |
| 9. No. 2 shift rail | 19. Interlock pin |
| 10. C-ring | |

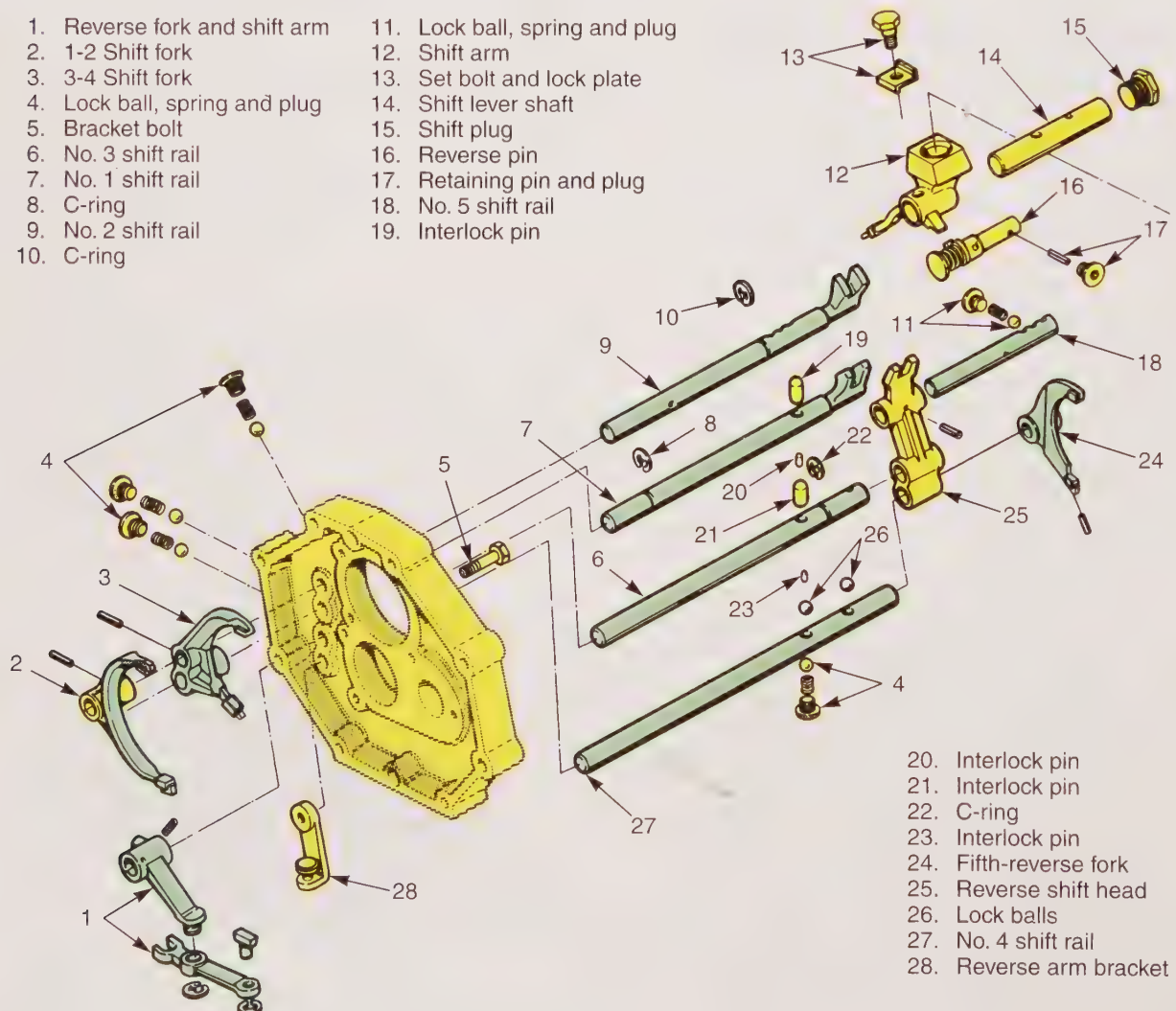


Figure 8-19. Some internal shift linkages use multiple shift rails, as seen in this exploded view. Note that the lock ball, spring, and plug assemblies shown in the illustration serve as detents. These detent ball assemblies hold the rails into whatever gear is selected. Interlock pins make it impossible to move more than one rail at a time. (Chrysler)

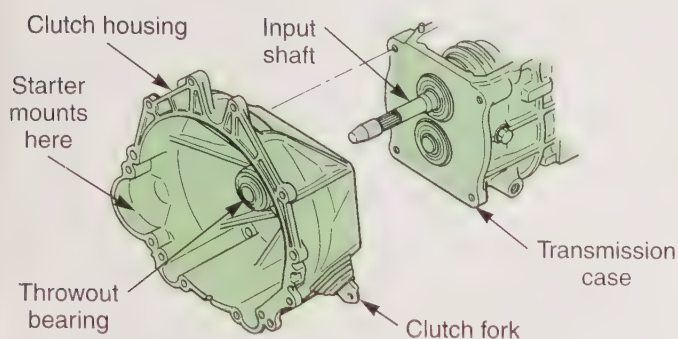


Figure 8-20. The transmission case provides a mounting surface for the clutch housing. Some transmission cases and clutch housings, however, are a combined integral casting. (Chrysler)

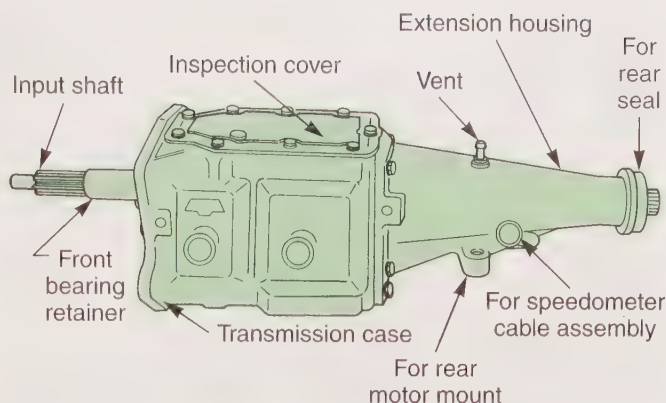


Figure 8-21. The transmission case supports, aligns, and serves as a mounting surface for the transmission components. The case also contains the transmission lubricant. (General Motors)

point for the extension housing and external shift linkage. **Figure 8-21** illustrates a typical transmission case. There are many variations of this basic design, but the transmission case always serves the same purpose.

Transmission cases can be made of cast iron or aluminum. Many cases contain pressed-in bearings to support rotating shafts. Most manual transmissions have a lubricant fill plug and, sometimes, a drain plug.

One modern version of the transmission case is shown in **Figure 8-22**. The case is made up of multiple pieces, including an adapter plate, or center support, which serves as the backside of the case. The adapter plate separates the transmission case and extension housing. The transmission shafts and gears are supported at the adapter plate and at the front and rear supports. This design makes the transmission easier to service.

The opening in the front of the transmission case is covered by the front bearing retainer, sometimes called the front bearing cap, or front cover. See **Figure 8-23**. The front bearing retainer covers the transmission's front bearing. The long hub of the retainer serves as the sliding surface for the clutch throwout bearing.

To eliminate lubricant leaks, a gasket is installed between the bearing retainer and the case. Also, an oil seal is installed in the retainer, **Figure 8-24**. The front bearing retainer seal prevents oil leakage between the cover and the transmission input shaft.

An access cover is commonly built into the top or side of the case. It allows access to the internal transmission parts for inspection or service. Depending on the design, the access cover may simply be a plain, flat plate or it may

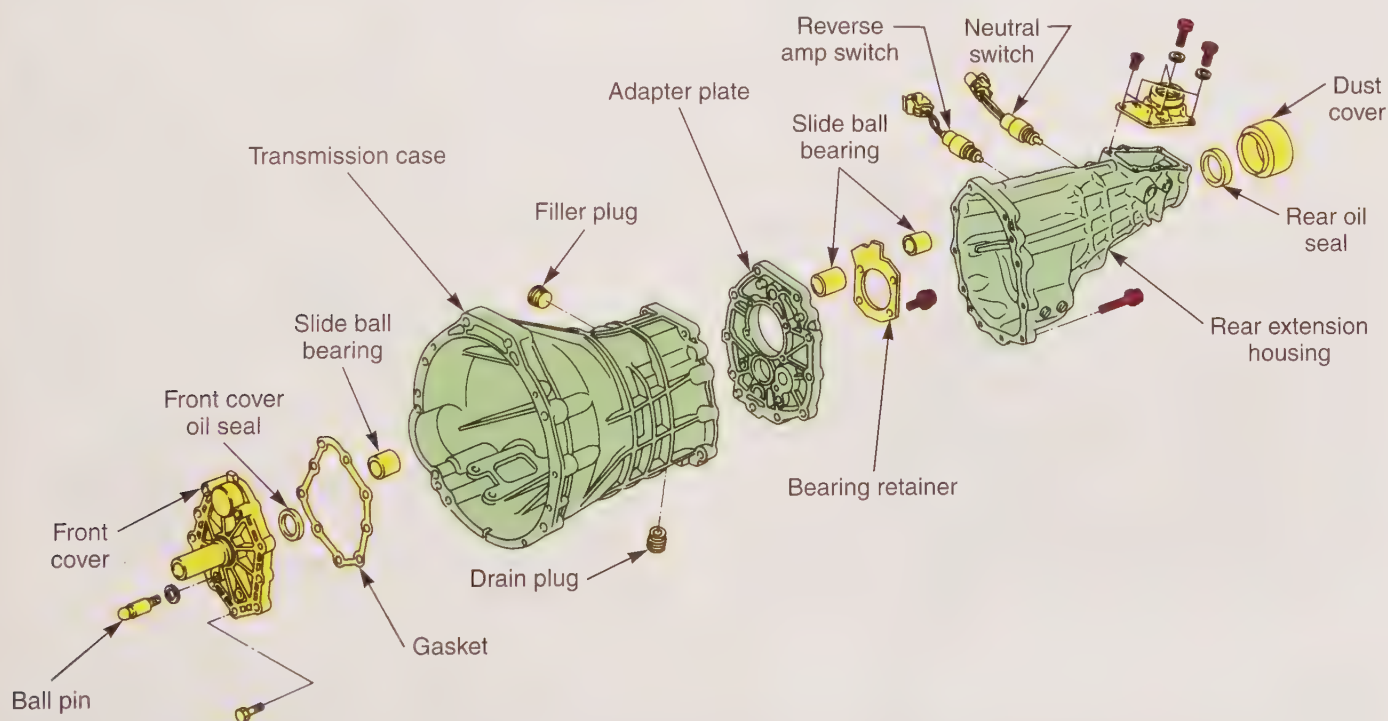


Figure 8-22. This transmission case design makes the transmission easier to service. The gearsets can be more readily exposed. The gear train can then be easily disassembled and repaired. Several manufacturers use variations of this design. (Nissan)

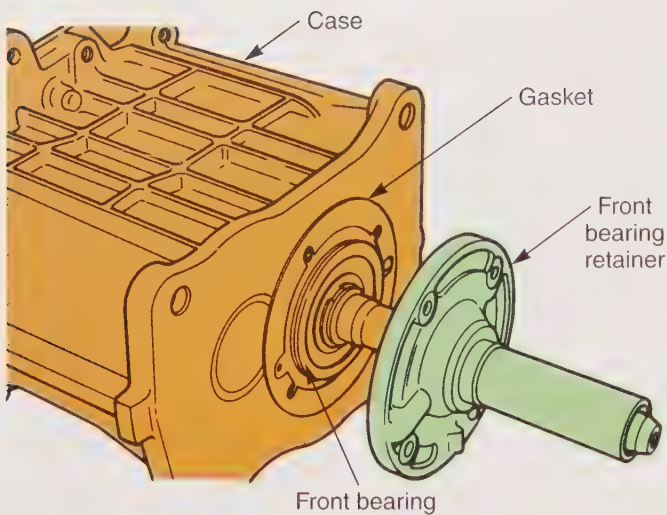


Figure 8-23. The front bearing retainer is usually attached to the transmission case by bolts. It holds the front bearing in place. A gasket and seal prevent lubricant leaks. (Chrysler)

be a contoured shape with built-in shift linkage. (Refer back to **Figure 8-18.**) On some floor-shift models, the gearshift lever goes directly through the cover. Note that all transmission covers use gaskets.

Extension Housing

The extension housing is made of aluminum or cast iron and provides protection for the end of the transmission output shaft. In some designs, the front of the extension housing holds the rear bearing, which supports the central portion of the output shaft. (In some designs, this bearing is held in the rear of the transmission case. In other designs, a center bearing is held in the center support and the rear bearing is held further back in the extension housing.) The

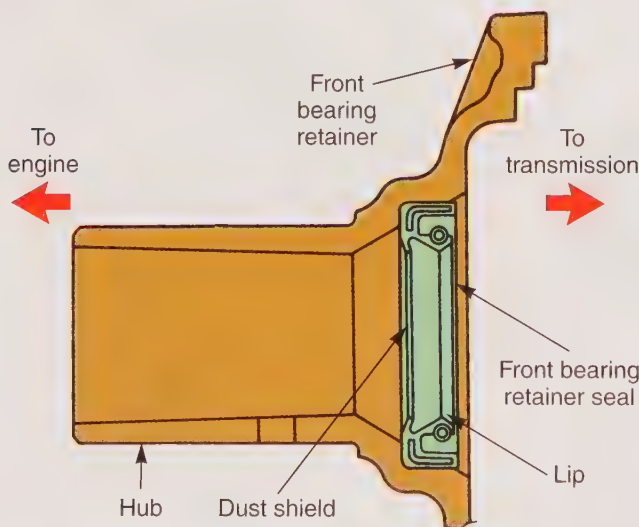


Figure 8-24. This shows a typical front bearing retainer seal. The sealing lip prevents oil loss, and the dust shield keeps out dirt and water. (General Motors)

front of the extension housing is bolted directly to the rear of the transmission case. To prevent lubricant leaks, there is usually a gasket between the case and extension housing.

The rear of the extension housing contains a bushing and seal. The transmission extension bushing supports and aligns the drive shaft assembly slip yoke, which, in turn, supports the transmission output shaft. The transmission rear seal prevents lubricant leaks and keeps dirt and water out of the transmission. A typical extension housing is illustrated in **Figure 8-25.**

The transmission mount, which supports the transmission and also serves as the rear engine mount, is usually installed on the extension housing. The mount is an assembly essentially composed of a bracket and rubber pad or bushing. A flat surface is machined on the bottom of most extension housings. The surface is drilled to fit the transmission mount attaching bolts. In vehicles with internal shift linkage, the gearshift lever usually extends into the transmission at the extension housing. A boot is used to prevent the loss of oil and the entry of dirt and water. The boot is usually held in place by a ring or bezel, which is attached to the extension housing with bolts or screws. The shift linkage extends from the extension housing into the transmission case.

Accessory Parts

Accessory parts may be bolted to or installed in the transmission case or extension housing. Fill and drain plugs, identification tags, shift levers, and boots are some common examples of accessory parts. Some of the accessories that are often attached to the transmission case or extension housing are shown in **Figure 8-26.**

Speedometer assembly

The extension housing usually contains the speedometer assembly. The speedometer assembly basically comprises the speedometer adapter and pinion gear, **Figure 8-27.** The speedometer adapter is installed with bolts or with a single bolt and clamp similar to a distributor hold-down clamp.

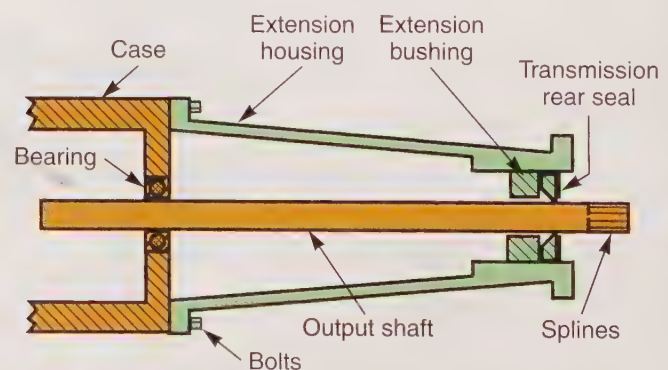


Figure 8-25. The extension housing keeps the output shaft aligned and seals the rear of the transmission. Common extension housing features are the extension bushing, rear seal, and housing-to-case gasket.

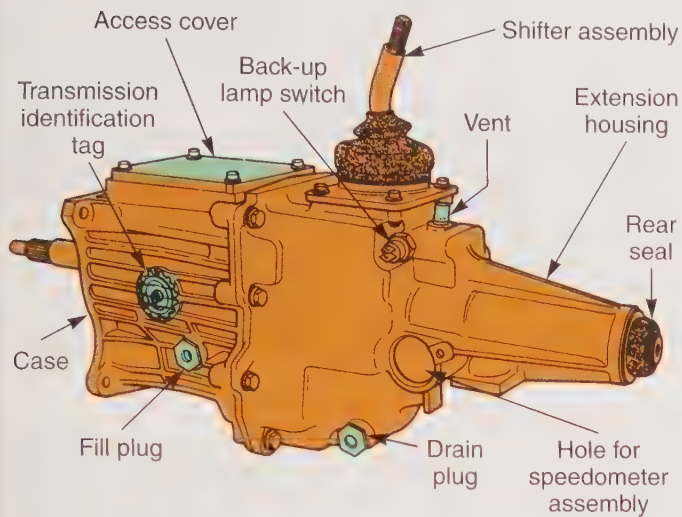


Figure 8-26. Accessory parts may be bolted to or installed in the transmission case or extension housing. Access covers, fill and drain plugs, identification tags, shift levers, and boots are some common examples. In addition, the transmission usually contains a vent somewhere at the top. The vent relieves pressure caused as the transmission lubricant heats up and expands. (Chrysler)

The speedometer gear mates with a worm gear on the output shaft, and the pinion gear shaft revolves inside the adapter. The adapter usually has both internal and external seals.

The speedometer assembly drives a cable, which runs through a housing. This cable assembly extends from the speedometer adapter in the extension housing to the speedometer head, or speed indicator assembly, in the

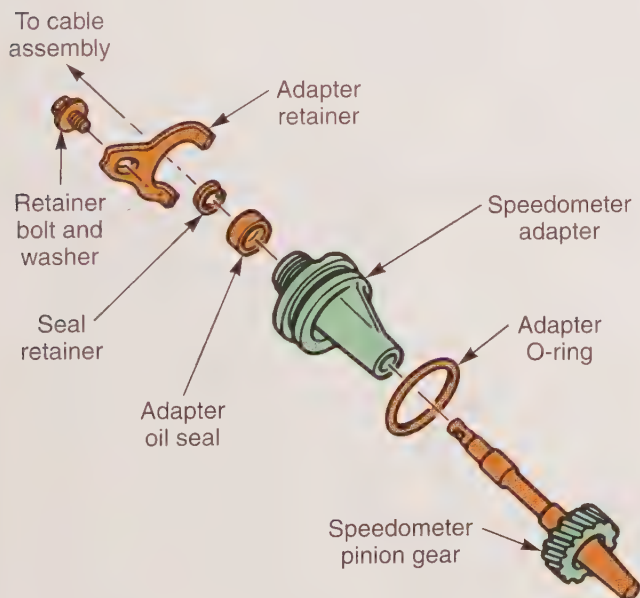


Figure 8-27. The speedometer pinion gear and adapter are usually installed in the extension housing. The adapter in this illustration is held in place by a single bolt and retainer. The speedometer pinion rotates inside of the adapter. (Chrysler)

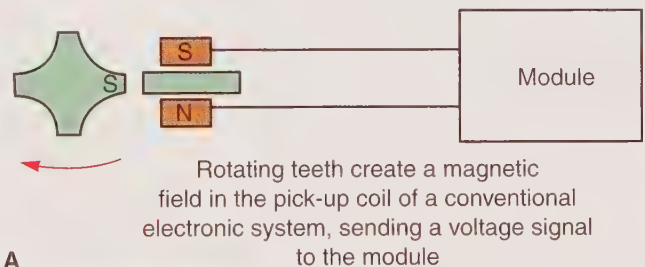
dash. Whenever the output shaft turns, the worm gear drives the pinion gear, and the speedometer cable turns. This makes the speedometer head register the road speed of the vehicle.

On many modern vehicles, the speedometer cable has been replaced with an electronic speed sensor, **Figure 8-28**. The rotation of the output shaft induces a small alternating (AC) current in the speed sensor. The vehicle computer reads this current as vehicle speed. The speed sensor signal is also used to operate the speedometer.

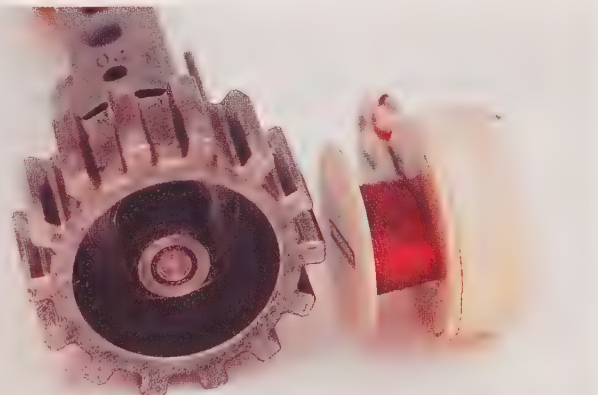
Switches, sensors, and solenoids

Most late-model manual transmissions are equipped with one or more switches, sensors, and sometimes, solenoids. Most of these devices will be screwed into tapped holes in the transmission case or in the extension housing. Solenoids help control transmission shifting. Switches are sometimes installed on the transmission to indicate to other vehicle systems that the transmission is in a particular gear.

For example, one switch is used to turn on the backup lights when the vehicle is shifted into reverse. Another component is used to prevent starter operation if the transmission is in gear. Some sensors tell the on-board computer when the transmission is in a particular gear so the computer can make adjustments to the engine fuel and ignition systems. Examples of some of these components can be seen in **Figure 8-22** and **Figure 8-26**.



A



B

Figure 8-28. A—The relationship of the speed sensor and the shaft-mounted rotor. Rotation of the rotor induces a magnetic field in the sensor. This creates a voltage signal that is sent to the vehicle's computer. B—This photo shows the relative positions of one sensor and rotor.

Some late-model transmissions have solenoids that prevent reverse engagement when the vehicle is moving forward. Other devices on some newer transmissions keep certain transmission gears from being selected when engine temperature is below normal.

Manual Transmission Gear Oil

Manual transmission gears are lubricated by gear oil contained in the transmission case. The rotating transmission gears throw oil onto the gear teeth and onto other stressed parts. This is called splash lubrication.

Manual transmissions are usually filled at the factory with 80- or 90-weight gear oil. In rare instances, heavy 140-weight oil is used. Occasionally, the manufacturer fills some manual transmissions with automatic transmission fluid; however, gear oil is recommended for topping off or refills.

Manual Transmission Power Flow

Manual transmission power flow can be understood by studying **Figure 8-29** through **Figure 8-35**. These figures show the gear train of a typical five speed manual transmission. Power flow, which is the path that power takes through the drive train, is depicted by arrows passing through the gears that are actually transmitting power. Study **Figure 8-29** to note the relative position of the various parts of the transmission.

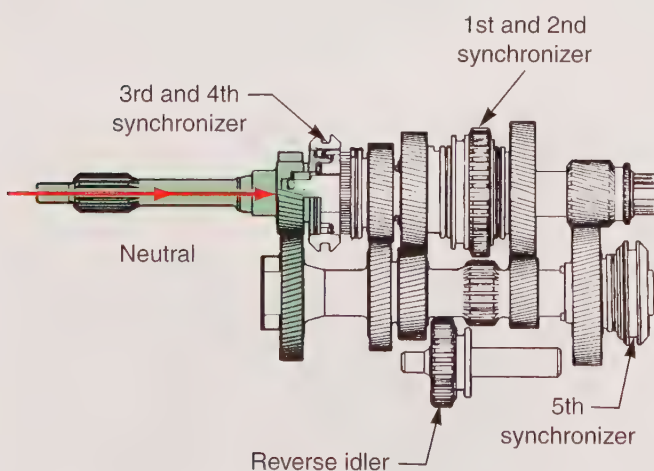


Figure 8-29. Note the major parts of the 5-speed transmission in this illustration. The transmission is similar to 3- and 4-speed transmissions, with input and output shafts, a countershaft with various gears, and a reverse idler gear. Note that fifth is an overdrive gear. All of the gears on the output shaft, except the fifth gear, can rotate on the shaft. The 1-2 and 3-4 synchronizer assemblies are splined to the output shaft. (Borg-Warner)

Neutral

In Neutral, the main drive gear turns the countershaft gear, **Figure 8-29**. All gears that are in constant mesh with the countershaft gear also turn. This includes first and second gears. On the fully synchronized transmission, it also includes the reverse and the reverse idler gears. However, since all synchronizer outer sleeves are in the Neutral position (centered on inner hub) and the reverse idler is in the disconnected position, no power reaches the output shaft, and it remains stationary. The vehicle does not move.

Reverse Gear

In reverse gear, power flows from the main drive gear into the countershaft gear, **Figure 8-30**. The reverse idler gear has been moved rearward and power from the countershaft gear flows into the reverse idler gear. The reverse idler gear directs power into the large gear on the outside of the rear or first-and-second gear synchronizer. Since the outer sleeve of the first-and-second gear synchronizer has been moved to the center position, power does not flow through either the first or second gears. The output shaft and synchronizer gear, however, remain locked together. Rotation is reversed between the main drive gear and the countershaft gear. It is reversed again between the countershaft gear and the reverse idler gear. The rotation is reversed one last time between the reverse idler gear and the first-and-second gear synchronizer/output shaft. Since the rotation has been reversed three times (an odd number) between input and output shafts, direction of the output shaft is opposite that of engine rotation.

Note that **Figure 8-30** shows the reverse idler gear below the countershaft. In the transmission, the idler gear is in mesh with the countershaft and first-and-second gear synchronizer teeth.

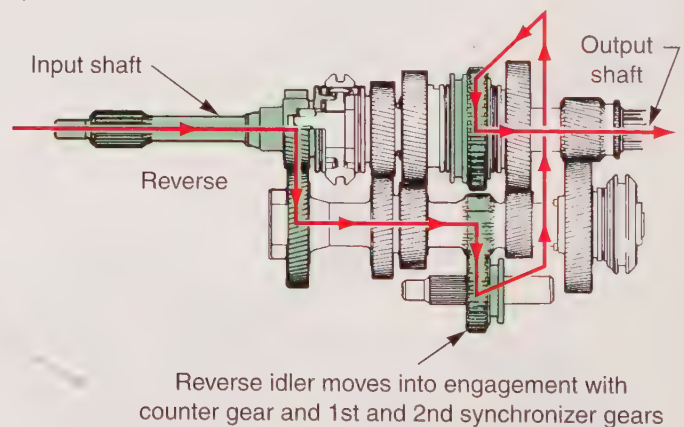


Figure 8-30. In reverse, the reverse idler gear moves toward the rear of the transmission and into engagement with the counter gear and the gear on the outer rim of the 1-2 synchronizer assembly. The reverse idler gear is drawn below the counter gear but is actually positioned between the counter gear and 1-2 synchronizer assembly. Power flows through the input gear, countershaft gear, reverse idler gear, 1-2 synchronizer assembly, and through the output shaft. This places the transmission in reverse gear. (Borg-Warner)

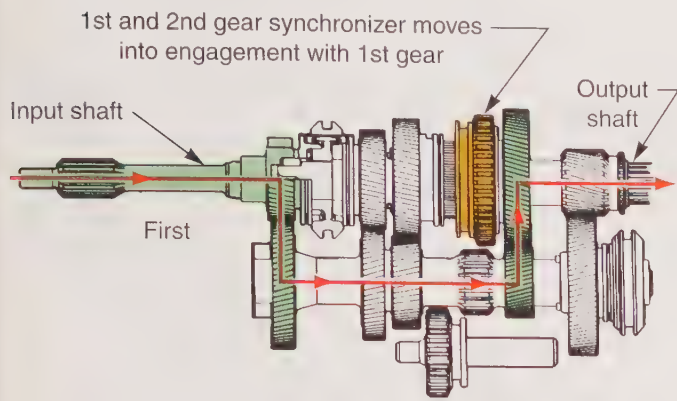


Figure 8-31. When the driver selects first gear, the 1-2 synchronizer assembly moves rearward into engagement with the first gear on the output shaft. Power flows through the input gear, first gear of the countershaft, the first gear on the output shaft, through the 1-2 synchronizer assembly, and to the output shaft. (Borg-Warner)

First Gear

In first gear, the input shaft's main drive gear turns the countershaft gear, reversing direction, **Figure 8-31**. The countershaft gear turns the low gear on the output shaft, reversing direction again so that the low gear turns in the same direction as the input shaft. Since the outer sleeve of the first-and-second gear synchronizer has been moved rearward, the low gear is locked to the output shaft. The vehicle is in first gear. The difference in countershaft gear and first gear teeth results in a gear ratio of about 3.5:1, and the vehicle accelerates easily.

Second Gear

In second gear, the input shaft's main drive gear turns the countershaft gear, reversing direction, **Figure 8-32**. The countershaft gear turns the second gear on the output shaft, reversing direction again. This double reversal makes the second gear turn in the same direction as the input shaft. Since the outer sleeve of the first-and-second gear synchronizer has

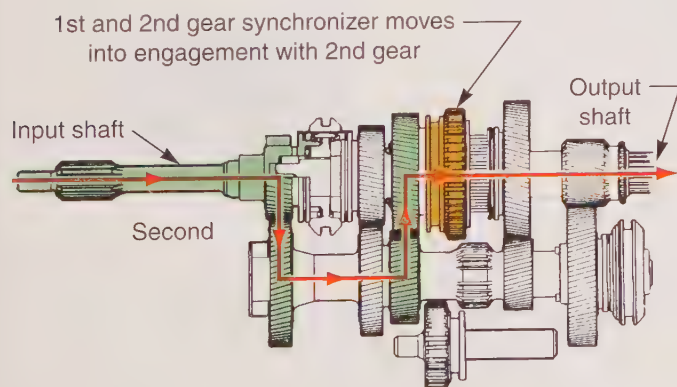


Figure 8-32. In second gear, the 1-2 synchronizer assembly moves forward into engagement with second gear on the output shaft. Power flows through the input gear, second gear on the counter gear, and the second gear on the output shaft, the 1-2 synchronizer assembly, and to the output shaft. (Borg-Warner)

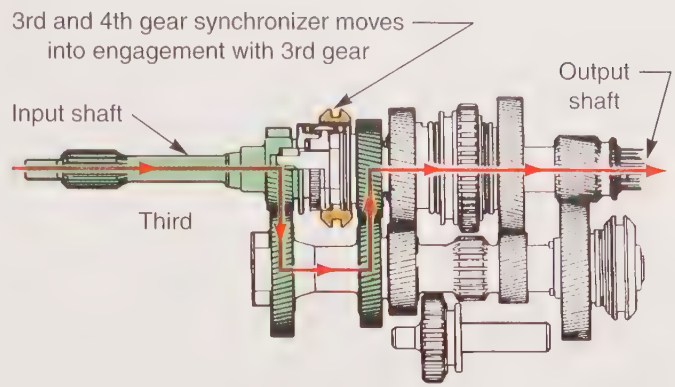


Figure 8-33. In third gear, the 3-4 synchronizer assembly moves rearward into engagement with third gear on the output shaft. Power flows through the input gear, third gear on the counter gear, and third gear on the output shaft, the 3-4 synchronizer assembly, and to the output shaft. (Borg-Warner)

been moved forward, the second gear is locked to the output shaft. The vehicle is in second gear. Note the difference in size between the countershaft and mainshaft teeth in second gear. A typical ratio in second gear is about 2.5:1.

Third Gear

In third gear, the input shaft's main drive gear turns the countershaft gear, reversing direction, **Figure 8-33**. The countershaft gear turns the third gear on the output shaft, reversing direction again. This double reversal makes the third gear turn in the same direction as the input shaft. Since the outer sleeve of the third-and-fourth gear synchronizer has been moved rearward, the third gear is locked to the output shaft. In third gear, the difference in size between the countershaft and second gear mainshaft teeth result in a ratio of about 1.5:1.

Fourth Gear

In fourth gear, the synchronizer outer sleeve moves forward, engaging the main drive gear, **Figure 8-34**. This

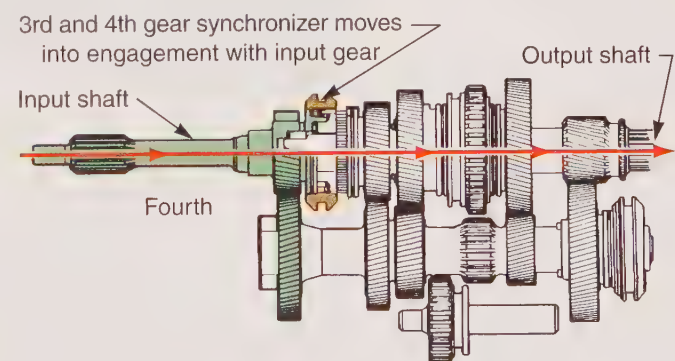


Figure 8-34. When fourth gear is selected, the 3-4 synchronizer assembly moves forward into engagement with the input shaft. Power flows from the input shaft through the 3-4 synchronizer assembly to the output shaft. This gear bypasses the countershaft. The transmission is in direct drive. (Borg-Warner)

locks the input and output shafts together. This is direct drive, or a 1:1 gear ratio. Notice that the countershaft gear is not used to transmit power in direct drive. This is true of direct drive in any manual transmission.

Fifth Gear

In fifth gear, the input shaft main drive gear turns the countershaft gear, reversing direction, **Figure 8-35**. The fifth gear synchronizer outer sleeve moves forward. This engages the fifth gear with the counter gear. Since the fifth gear is already in mesh with a gear on the output shaft, the synchronizer movement locks together the counter gear and the output shaft. The difference in gear sizes results in a 7:1 gear ratio.

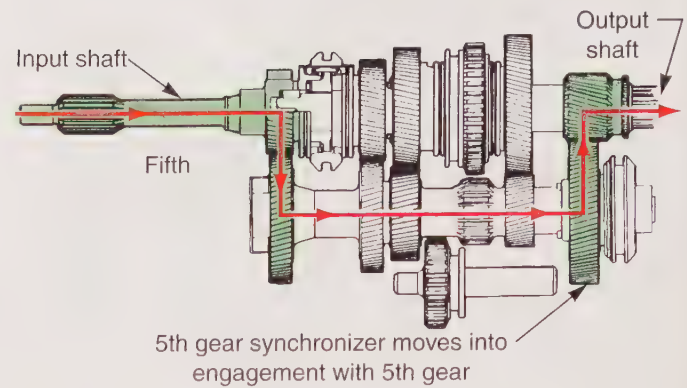


Figure 8-35. In fifth gear, the fifth gear synchronizer assembly moves forward into engagement with the fifth gear on the countershaft. Power flows through the input gear, fifth gear on the counter gear, fifth gear synchronizer assembly, and fifth gear on the output shaft. (Borg-Warner)

Manual Transmission Designs

Today, there are many manual transmission designs for rear-wheel drive vehicles. Transmissions that have more forward speeds provide a better selection of gear ratios. Extra gear ratios are needed for the smaller, low-horsepower, high-efficiency engines of today. Some of the most common transmissions are discussed in the following section.

4-Speed Transmissions

The **4-speed transmission** has four forward gears. These transmissions were the high-performance models on cars in years past. Today, 4-speeds are still occasionally used. Older 4-speeds usually had external linkage. The linkage on newer models is usually internal. **Figure 8-36** shows a common 4-speed transmission.

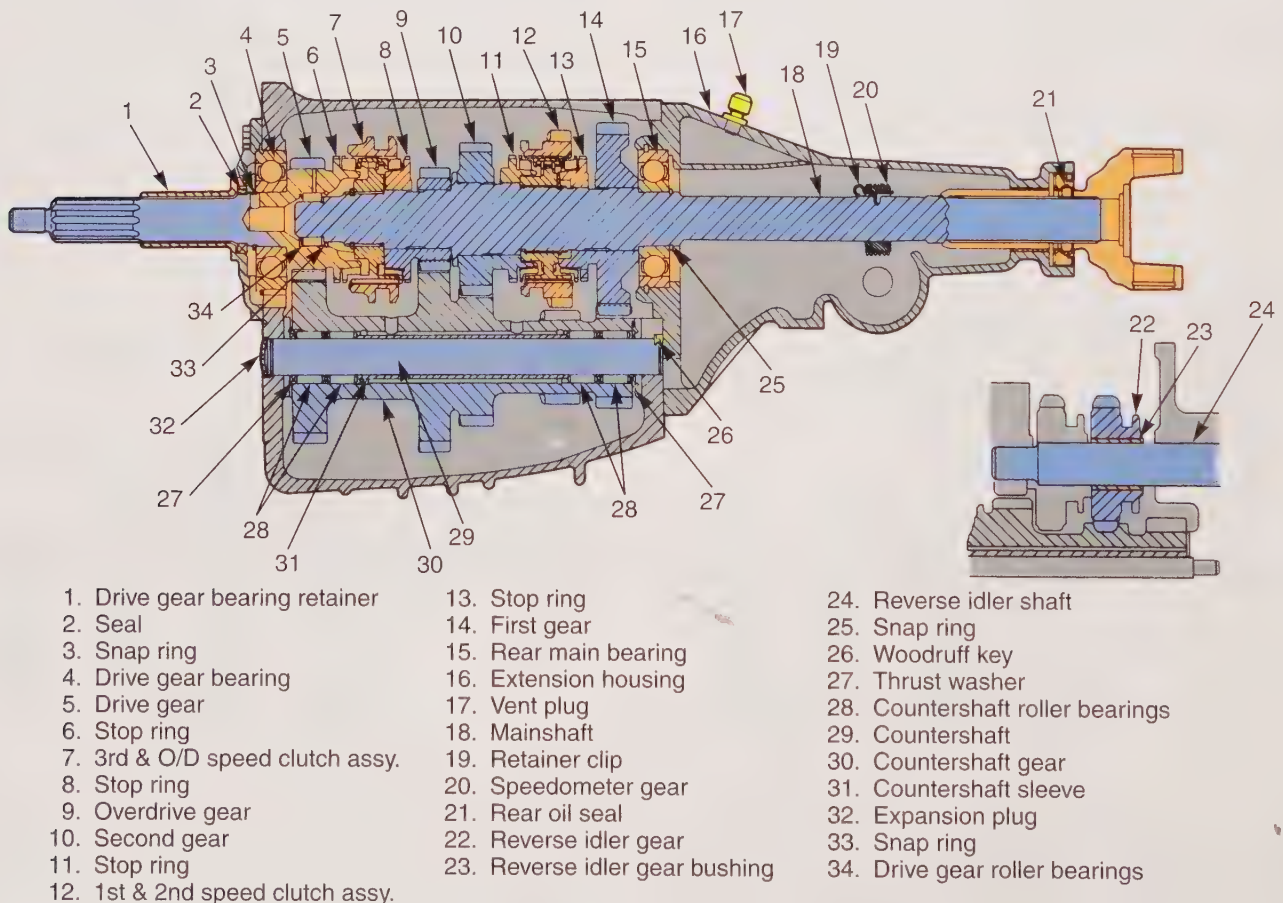


Figure 8-36. This is one version of a 4-speed transmission with a floor shift. (General Motors)

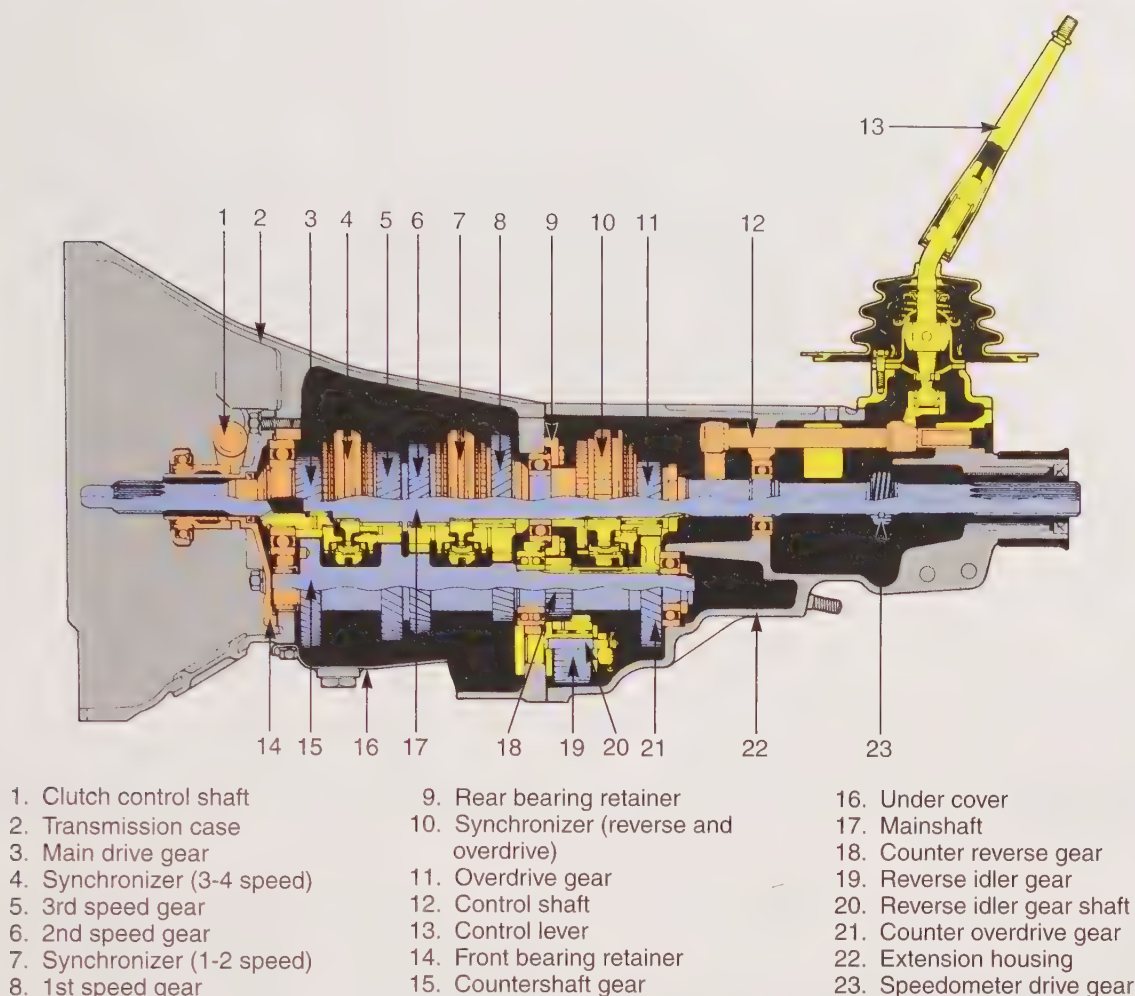


Figure 8-37. The 5-speed resembles the 4-speed transmission. Fifth gear is usually an overdrive. In some instances, overdrive has been added to a 4-speed by extending the countershaft gear assembly and transmission case. An extra gear is also added to the output shaft.

5-Speed Transmissions

The **5-speed transmission** resembles a 4-speed, **Figure 8-37**. These transmissions have five forward gears. Fifth gear is usually overdrive. Linkage and case materials are similar to the 4-speed. It is always used with a floor shift. Many 5-speed transmissions were created from existing 4-speeds by adding extra gears on the countershaft and output shaft. 5-speed transmissions are popular because of the improvement in gas mileage with the overdrive gear.

6-Speed Transmissions

The **6-speed transmission** has six speeds (gear ratios) in a compact case. In some instances, both fifth and sixth gears are overdrives. The linkage is usually internal. A 6-speed is often used with high-performance engines to obtain high performance while maintaining acceptable gas mileage. **Figure 8-38** shows a typical 6-speed transmission.

Summary

The vehicle driver selects manual transmission gears. Operation of a manual transmission is simple. The clutch pedal is depressed, and the proper gear is selected by using the gearshift lever. Then, the clutch pedal is released to allow power to flow to the rear wheels.

There are seven major parts to a manual transmission. These are the transmission shafts and gears, the synchronizers, the shift forks and linkage, and the transmission case and extension housing.

Transmission shafts are used to support gears and to transmit motion. A shaft may rotate, or it can be a stationary support for a moving gear. The major shafts in a manual transmission are the input shaft, countershaft, output shaft, and reverse idler shaft.

Transmission gears may rotate on transmission shafts or may be solidly connected to them. Gears transmit power and provide different gear ratios and a way to reverse the vehicle.

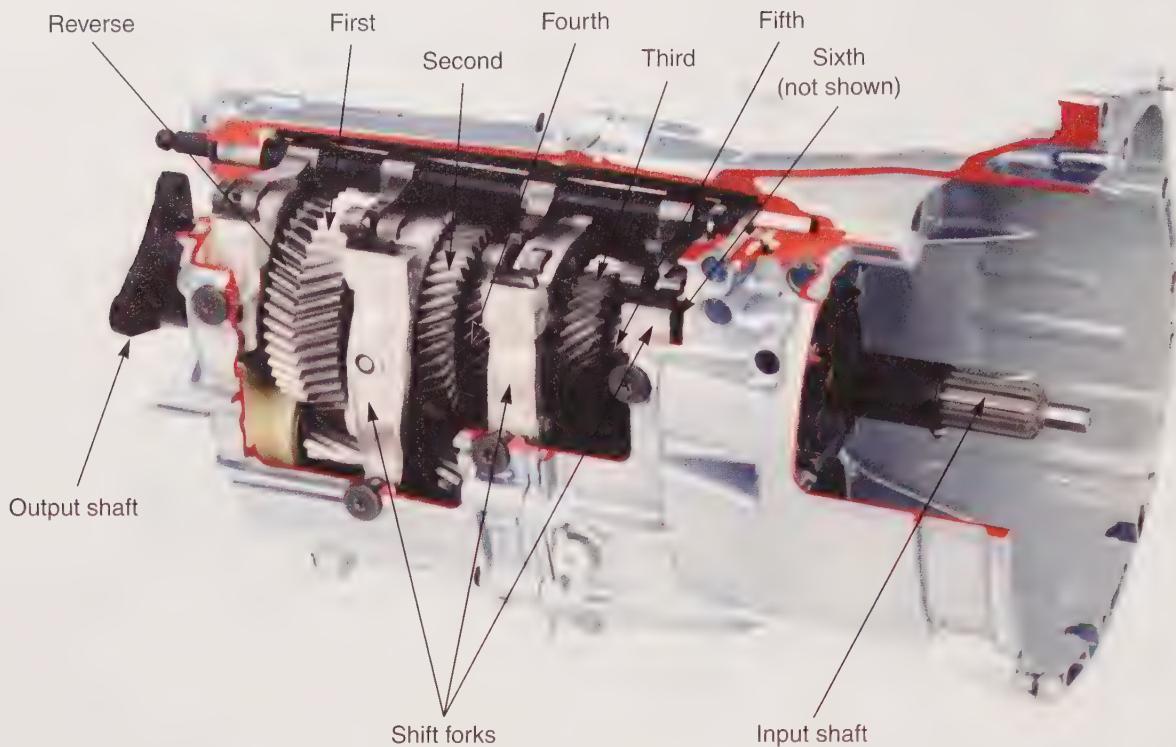


Figure 8-38. This 6-speed transmission is used on some vehicles, usually with high-performance engines. The arrangement is similar to 4- and 5- speed transmissions. In this transmission, only sixth gear is an overdrive. (ZF)

The engine turns the input shaft and main drive gear whenever the clutch is engaged. The main drive gear is always in mesh with the countershaft gear. This gear turns whenever the main drive gear turns. The output shaft contains gears that provide forward speeds. It also contains reverse gear. The reverse idler gear is in mesh with the countershaft gear. Through the idler gear, rotational direction of the output shaft is made opposite of the input shaft. In this way, the vehicle can be reversed.

Synchronizers are used to select various gears by matching gear speeds to avoid gear clash. They consist of a splined outer sleeve, an inner hub, and blocking rings, which match cone-shaped extensions on mating gears. When the synchronizer is pushed into engagement with the cone, it acts as a clutch, speeding up or slowing down one gear to match the speed of the output shaft.

Most modern transmissions are synchronized in all forward gears. In some transmissions, however, low and reverse gears are selected by sliding the main drive gears directly into mesh with the countershaft gears.

The vehicle driver operates the synchronizer outer sleeves through shift forks. Shift forks slip into grooves cut in the outer sleeves. The shift fork moves in a straight line to push the sleeve into engagement with a mating gear. The sleeve can continue to rotate as it is moved.

The driver operates the shift forks through a series of shafts, levers, links, and sometimes cables. External shift linkage is a system that is identified as a series of rods and levers that connect to the outside of the transmission. External shift linkage may be connected to the gearshift lever either on the steering column or on the floor.

Internal shift linkage is found only on transmissions with floor-mounted gearshift levers. Except for the gearshift lever, all linkage is internal to the transmission. This type of linkage may employ a single shifter shaft or several shift rails. The shift forks are positioned along the shaft.

The transmission case houses, supports, and aligns the rotating transmission components. It forms a reservoir for lubricant. It is the attaching point for the clutch housing, extension housing, shift linkage, and other components. Many modern transmissions are made with a center support.

The front bearing retainer is installed on the front of the transmission case, around the input shaft. It forms a support for the front bearing. The clutch throwout bearing slides on the nose of the front bearing retainer.

The extension housing supports and protects the end of the transmission output shaft. The front of the extension housing is bolted to the transmission case. The extension housing also contains the speedometer pinion gear and adapter and worm gear. The transmission mount is usually attached to the extension housing.

Most late-model transmissions will be equipped with one or more electrical switches, sensors, and solenoids. Switches and sensors are used to turn on the backup lights or to prevent starting the engine when the transmission is in gear. Sensors are used to provide information to engine control computers. Solenoids help control transmission shifting.

There are many different kinds of rear-wheel drive manual transmissions. Models with only three forward speeds are obsolete and will be found only in very old

vehicles. The 4- and 5-speed models are the most common today. The 6-speed model is increasingly being used to obtain acceptable gas mileage on high-performance vehicles.

Review Questions—Chapter 8

Answer the following questions using the information provided in this chapter.

1. What is the purpose of a transmission?
 2. The _____ supports the transmission shafts, forms a reservoir for lubricant, and provides an attaching point for other components.
 3. The _____ provides protection for the end of the transmission output shaft and is the usual location for the transmission mount.
 4. The four types of transmission shafts are the _____ shaft, _____, _____, and _____ shaft.
 5. Why are thrust washers used in transmissions?
 6. To lock mainshaft gears to the output shaft and eliminate gear clash in the process, constant-mesh transmissions use _____.
 - (A) clutch gears
 - (B) sliding gears
 - (C) shift rails
 - (D) synchronizers
 7. In your own words, how do synchronizers operate?
 8. Each _____ gear comprises two sets of teeth.
 9. In an internal shift linkage, shifting is accomplished by means of a(n) _____ attached to a _____ shaft.
 10. What types of lubricant are used in a manual transmission?
 11. On a separate sheet of paper, sketch the power flow through a typical 5-speed transmission in each gear position.
 12. In your own words, describe the internal action of the 5-speed transmission in each gear position.
1. Each of the following is found in manual transmissions *except*:
 - (A) input shafts.
 - (B) output shafts.
 - (C) countershafts.
 - (D) stator shafts.
 2. Rearward movement of the input shaft is usually prevented by _____.
 - (A) snap rings
 - (B) the output shaft
 - (C) the main drive gear
 - (D) the front bearing retainer
 3. Which of the following gears is used for reverse?
 - (A) Spur gears.
 - (B) Helical gears.
 - (C) Cluster gears.
 - (D) Main drive gears.
 4. Which of the following contains the gears that provide all forward speeds and reverse?
 - (A) Input shaft.
 - (B) Clutch shaft.
 - (C) Output shaft.
 - (D) Reverse idler shaft.
 5. Technician A says that each mainshaft gear comprises two sets of teeth. Technician B says that the main drive gear has three sets of teeth. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
 6. To shift from one gear to another, constant-mesh manual transmissions require _____.
 - (A) idler gears
 - (B) bearings
 - (C) planetary gears
 - (D) synchronizers

ASE-Type Questions—Chapter 8

7. Technician A says that the outer sleeve of a synchronizer assembly does not rotate until it engages the blocking ring. Technician B says that shift forks move the outer sleeve while permitting sleeve rotation to continue. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
8. In an internal shift linkage, which of the following locks out all other gears *except* the one selected?
 - (A) Locknut.
 - (B) Blocking ring.
 - (C) Interlock plate.
 - (D) Block synchronizer.
9. Each of the following is used to cover the opening in the front of the transmission case *except*:
 - (A) the front cover.
 - (B) the front bearing cap.
 - (C) the front bearing retainer.
 - (D) the clutch housing.
10. In reverse gear, rotation between input and output shafts is reversed _____.
 - (A) once
 - (B) twice
 - (C) three times
 - (D) five times
11. On a fully synchronized transmission in Neutral, each of the following is driven by the main drive gear *except*:
 - (A) second gear.
 - (B) the reverse idler gear.
 - (C) the countershaft gear.
 - (D) the output shaft.



Chapter 9

Manual Transmission Problems, Troubleshooting, and Service

After studying this chapter, you will be able to:

- ☐ Name and describe common types of problems that can occur in a manual transmission.
- ☐ Adjust external shift linkages.
- ☐ Evaluate manual transmission problems to determine if removal is necessary.
- ☐ Remove a manual transmission from a vehicle.
- ☐ Disassemble a manual transmission.
- ☐ Inspect the parts of a manual transmission both visually and by measurement.
- ☐ Assemble a manual transmission.
- ☐ Install a manual transmission in a vehicle.
- ☐ Distinguish between safe and unsafe manual transmission service procedures.

Technical Terms

Lubricant leakage

Gear clash

No-drive condition

Abnormal noise

Hard shifting

Split-case transmission

Gear jumpout

Dummy shaft

Gear slipout

Introduction

Although manual transmissions are not as common as they once were, many are still installed on modern vehicles. New manual transmissions come in a variety of designs, with as few as four forward speeds or as many as six. The automotive technician must know how to properly diagnose and service these assemblies. If you study the information presented here, you will learn these important skills. In addition, you will have a solid basis for learning how to diagnose and service other gear units, such as those found in front-wheel drive manual transaxles and four-wheel drive transfer cases. Many of the techniques applied in this chapter will also be applied in later chapters.

This chapter is intended as a general guide to manual transmission diagnosis and service. It covers in-car service procedures, such as servicing the transmission external shift linkage, as well as performing major overhauls. The information presented here will help you understand the troubleshooting and diagnostic information found in factory service manuals. The removal and installation steps presented in this chapter will be applicable to almost any kind of transmission. **Figure 9-1** shows typical transmission problems. Study them carefully.

Manual Transmission Problems and Troubleshooting

The transmission technician should be as good at diagnosing manual transmission problems as he or she is at

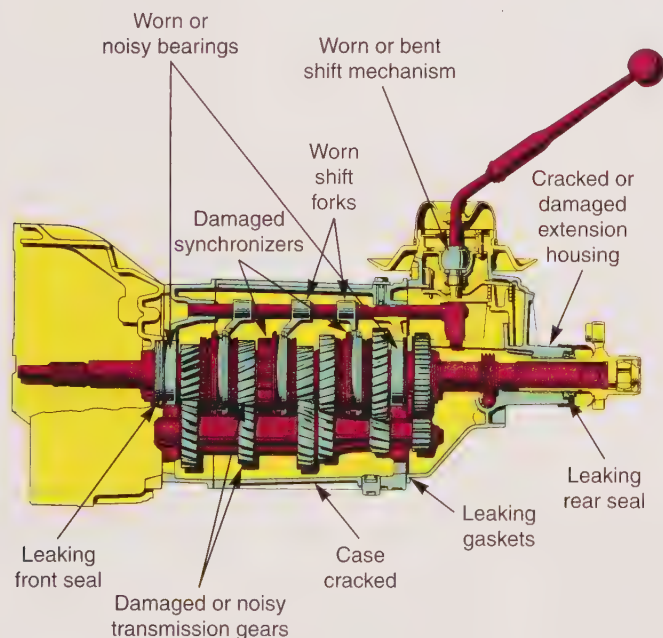


Figure 9-1. Study the types of problems found in manual transmissions. (Fiat)

repairing them. The final outcome of the troubleshooting process should be knowing what the problem is before you begin repairs. If you do not know what is really wrong with a transmission, your chances of repairing it properly are slim. This section is designed to make troubleshooting transmission problems easier.

Since manual transmissions consist of mechanical parts, most manual transmissions will wear out, usually because of high mileage. Transmissions may require repair at low mileage because of careless driving habits. For example, attempting to change gears too quickly can chip or break teeth on the gears or synchronizers. Skipping too many gears when downshifting at high vehicle speeds or releasing the clutch pedal before gears are completely engaged can also cause teeth to chip or break. Synchronizer rings, in particular, are made from soft metal—brass, bronze, or copper. Any type of rough shifting can easily damage them.

A lubricant level that is too low is another source of manual transmission problems. Manual transmissions are lubricated by oil that is thrown onto the moving parts as they rotate. This method, called splash lubrication, works only if the oil in the transmission is at the proper level. If the level is allowed to become too low, the moving parts will be damaged.

Water in a transmission can also cause problems. If the vehicle is driven through deep water, some water may enter through the transmission vent. Water will contaminate the oil and destroy its lubrication value. Gears and bearings that run in water can become pitted, requiring replacement.

You should start your diagnosis of a manual transmission problem by finding out why the vehicle was brought in for service. Have the owner or driver describe the problem before you perform any other diagnostic steps.

Some problems can be diagnosed with the vehicle on a lift, while others require that you take a test-drive. When test-driving a vehicle, determine in which transmission gear or gears and at which speed the problem occurs. If possible, take the driver of the vehicle with you, and have him or her point out the particular problem while it occurs.

Once you have identified the operational problem, check out the easiest possible solution first. You should always proceed from the easiest solution to the hardest solution. For instance, you should check the oil level and linkage adjustments before removing and disassembling the transmission. Consider all possibilities, even the most unlikely, and use well-thought-out methods to find solutions. Always avoid guesswork, as this is seldom profitable.

Many manual transmission problems can be solved by simple linkage adjustments or by adding oil to the transmission. Every manual transmission that is brought in for service should be checked for clutch- and shift-linkage condition and adjustment. The transmission oil level should be checked, and the proper grade and type of lubricant should be added, if necessary. If the oil level is low, you should check for leaks.

Problems exhibited in manual transmission operation are presented in detail in the upcoming paragraphs. **Figure 9-2** summarizes some common conditions and their causes and corrections.

Manual Transmission Diagnosis

Condition	Possible cause	Correction
Leaks lubricant	a. Cover loose. b. Cover gasket loose or defective. c. Front bearing retainer loose, broken, or gasket defective. d. Front bearing retainer seal defective. e. Output shaft seal worn. f. Countershaft lose in case. g. Lubricant level too high. h. Shaft expansion plugs loose in case. i. No sealer on bolt threads. j. Damage shifter shaft seal. k. Vent plugged. l. Wrong lubricant. m. Cracked case or extension housing. n. Drain or filler plug loose.	a. Tighten cover. b. Tighten cover and/or replace gasket. c. Tighten retainer, replace gasket or retainer. d. Replace seal. e. Replace seal. f. Replace case. g. Drain to level of filler plug. h. Replace plugs. Use sealer. i. Seal threads. j. Replace seal. k. Open vent. l. Drain and refill with recommended lubricant. m. Replace case or housing. n. Tighten plug.
Shifts hard	a. Excessive clutch pedal free travel. b. Worn or defective clutch. c. Failure to fully depress clutch pedal when shifting. d. Shift cover loose. e. Shift fork, shafts, levers, or detents worn or loose. f. Improper shift linkage adjustment. g. Linkage needs lubrication. h. Linkage binding, bent, or loose. i. Wrong transmission lubricant. j. Insufficient lubricant. k. Excess amount of lubricant. l. Transmission misaligned. m. Front bearing retainer loose or cracked. n. Synchronizer worn, damaged, or improperly assembled.	a. Adjust free travel. b. Replace worn parts. c. Instruct driver. d. Tighten cover. e. Tighten or replace. f. Adjust linkage. g. Lubricate. h. Free, straighten, or tighten as needed. i. Drain and fill with recommended lubricant. j. Add lubricant to filler plug level. k. Drain to level of filler plug. l. Correct alignment. m. Tighten or replace retainer. n. Replace or reassemble synchronizer.
Slips or jumps out of gear	a. Transmission loose or misaligned. b. Clutch housing loose or misaligned. c. Shift linkage improperly adjusted. d. Shift rail detents worn or detent springs weak. e. Synchronizer clutch sleeve teeth worn. f. Loose shifter cover. g. Shift fork, shaft, or levers worn. h. Worn teeth on main drive gear or other gears. i. Worn countershaft gear assembly bearings and/or thrust washers. j. Worn reverse idler gear assembly bushing or bearings. k. Worn output shaft pilot bearing. l. Front bearing retainer loose. m. Other parts striking shift linkage. n. Worn input or output shaft bearings. o. Worn input shaft bushing in flywheel. p. Bent output shaft.	a. Tighten and/or align. b. Tighten and/or align. c. Adjust linkage. d. Replace detents and/or springs. e. Replace synchronizer. f. Tighten cover. g. Replace worn part. h. Replace input shaft or gears. i. Replace countershaft gear bearings and washings. j. Replace gear, bearings, and shaft. k. Replace rollers, replace shafts if necessary. l. Tighten retainer. m. Make adjustments to provide clearance. n. Replace bearings. o. Replacing bushing or bearing. p. Replace shaft.

(continued)

Figure 9-2. Manual transmission diagnosis chart.

Condition	Possible cause	Correction
Gear clash during downshifting	a. Synchronizer worn, damaged, or improperly assembled. b. Shifting too fast (ramming into lower gear). c. Shifting to a lower gear when road speed is excessive. d. Clutch not releasing properly. e. Excessive output shaft endplay. f. (See shifts hard.)	a. Replace or reassemble synchronizer. b. Force into gear with a smooth, slower shift. c. Slow down to appropriate speed before shifting. d. Adjust or repair as needed. e. Adjust endplay.
Gear clash shifting from Neutral to Reverse	a. Insufficient clutch pedal free travel. b. Worn lubricant. c. Engine rpm too high. d. Driver not waiting long enough after depressing clutch. e. Sticking clutch pilot bearing.	a. Adjust free travel. b. Drain and fill with correct lubricant. c. Set to correct idle rpm. d. Instruct driver. e. Replace pilot bearing.
Transmission noisy in Neutral	a. Worn or damaged front bearing. b. Worn or damaged gears. c. Lack of lubrication. d. Countershaft gear assembly bearings worn or damaged. e. Output shaft pilot bearing worn or damaged. f. Countershaft gear antilash plate worn or damaged. g. Lubricant contaminated with broken bits of gears, bearings, or other parts.	a. Replace bearing. b. Replace gears. c. Fill to filler plug. d. Replace bearings, countershaft gear, and countershaft. e. Replace all rollers. f. Replace plate or countergear as required. g. Disassemble, clean, and repair transmission.
Transmission noisy in direct drive	a. Defective front (input shaft) bearing. b. Defective output shaft bearing. c. Defective synchronizer assembly. d. Defective speedometer gears.	a. Replace bearing. b. Replace bearing. c. Replace damaged parts. d. Replace damaged parts.
Transmission noisy in reduction gears	a. Defective countershaft bearings. b. Defective synchronizer assembly. c. Counter gear or bushings worn, loose.	a. Replace bearings. b. Replace damaged parts. c. Replace damaged parts.
Transmission noisy in overdrive gears	a. Defective countershaft bearings. b. Defective synchronizer assembly. c. Counter gear or bushings worn, loose.	a. Replace bearings. b. Replace damaged parts. c. Replace damaged parts.
Transmission noisy in reverse	a. Defective reverse idler gear. b. Defective countershaft bearings. c. Defective reverse synchronizer assembly. d. Counter gear or bushings worn, loose.	a. Replace gear. b. Replace bearings. c. Replace damaged parts. d. Replace damaged parts.
Transmission noisy in all gears	a. Insufficient lubrication. b. Worn or damaged bearings. c. Worn or damaged gears. d. Wrong lubricant. e. Excessive synchronizer wear. f. Defective speedometer gears. g. Transmission misaligned. h. Excessive input or output shaft and/or countershaft gear endplay. i. Contaminated lubricant.	a. Fill to filler plug. b. Replace bearings. c. Replace gears. d. Drain and fill with recommended lubricant. e. Replace synchronizer. f. Replace gears. g. Correct alignment. h. Adjust endplay. i. Disassemble, clean, and repair transmission.

Figure 9-2. (continued).

Lubricant Leakage

Transmission **lubricant leakage** is an unwanted loss of lubricant from inside of the transmission. A transmission case should be oil-free on the outside. (A slightly rusty case is normal.) Lubricant levels may drop slightly in a manual transmission because some of the lubricant evaporates. However, if the oil level is very low, there is probably a leak somewhere. Most manual transmission oil leaks are first noticed when oil spots show up under the vehicle.

When a vehicle is brought in because of leaking lubricant, make sure the leak is really from the transmission. Engine oil, brake fluid, power steering fluid, or engine coolant could be dripping off the transmission case. Fluids from the front of the vehicle are often carried to the back by airflow under the moving vehicle. If the case has oil on it but the oil level is normal, something else may be leaking. Finding the exact source of the leak can be difficult. It may be necessary to completely clean the case and put the vehicle up on a lift to isolate the exact source.

Once you are sure the transmission is leaking fluid, you must check for the location and cause. A usual cause of leakage is worn or damaged gaskets or seals. Gaskets are found in the case and the extension housing, the front bearing retainer, and the transmission top or side cover. Seals are used at the front bearing retainer, between the retainer and the input shaft. They are also used at the shifter shaft, between the case and extension housing, and at the rear of the extension housing.

Loose bolts are another common cause of leaks. Other possible causes include loose countershaft or idler shaft sealing plugs, lack of sealer on bolts, a loose drain or fill plug, a hairline crack in the transmission case, or a broken front bearing retainer. Leaks are sometimes caused by too much oil in the transmission. If the oil level is too high, oil may leak from the transmission vent or from otherwise good seals.

If the leak is caused by loose bolts or overfilling, correcting the leak is simple. If a seal or gasket is leaking, however, or if other transmission parts are causing the leak, the transmission may require removal to gain access to the parts.

No-Drive Condition

When the transmission will not transmit power from the engine to the drive wheels, a **no-drive condition** exists. If only one gear will not transmit power, that gear is probably stripped. If the transmission will not move in any gear, the most likely cause is stripped input shaft and countershaft gears or a broken input or output shaft. Often, the shift linkage is disconnected and will be unable to select a gear. Sometimes, the transmission will be locked in two gears, and the vehicle will be unable to move. This is often caused by a defect in the shift linkage or shift interlock.

If a gear is stripped or a shaft is broken, the engine idles easily with the clutch engaged and the defective gear selected. If the transmission is locked, engaging the clutch

kills the engine. If the linkage is working properly, the no-drive problem is caused by internal damage, and the transmission must be removed from the vehicle for repairs.

Hard Shifting

Hard shifting is a condition that occurs when the shift lever is difficult to move from gear to gear. In some instances, only one gear is hard to select; in others, all shifting may be difficult.

The usual causes of hard shifting are bent or worn shift linkage and linkage in need of lubrication. Hard shifting may also be caused by binding of the shift rails or forks. Occasionally, hard shifting may be caused by a misaligned transmission case or a problem in the clutch.

Hard shifting can be diagnosed easily. If the gearshift lever is hard to move even when the engine is stopped, the shift linkage is probably the source of the problem. If the gearshift lever moves easily when the engine is stopped but shifting becomes hard with the engine running, the problem is probably in the vehicle clutch, or else the case is misaligned.

In transmissions having an external shift linkage, hard shifting may be corrected by adjusting or lubricating shift linkages. In contrast, if internal parts of a shift linkage are bent or sticking, the transmission must be removed and disassembled to make repairs. Bad synchronizers, which can be responsible for hard shifting, or clutch problems will require transmission removal. Misalignment problems may require transmission removal; however, if the case is misaligned because of dirt or other foreign material, it may be possible to clean and realign it without removal.

Gear Disengagement

There are two closely related conditions in which transmission gears and synchronizers disengage on their own, causing a transmission to come out of gear. These conditions are known as gear jumpout and gear slipout.

With **gear jumpout**, the components are fully engaged but something happens to force them out of engagement, into Neutral. In the case of **gear slipout**, the gears and synchronizers are never quite fully engaged (but should be). When this happens, gear rotation tends to push the synchronizer outer sleeve and mating gear out of engagement.

Jumpout generally occurs when some outside force overcomes spring pressure in one of the detent holding mechanisms of the shift linkage. Often, there is a problem with the detent mechanism; the springs may be broken, or the detent notches may be worn. The problem could be in the shift rails of an internal shift linkage, for example, or it could be in the gearshift lever assembly. If the problem is a detent, the driver may falsely assume that the problem occurs in high gear only. The driver may only notice the problem in high gear because this is the only gear in which he or she is not holding the gearshift lever.

There are a number of conditions that can cause gear slipout. The first step in finding the cause of the problem is to determine which gear or gears are slipping out of engagement.

If the transmission slips out of a reduction gear, begin by checking for problems in the linkage. The linkage could be worn or improperly adjusted. There may be interference between the shift linkage and some other part of the vehicle, or the shift linkage may be binding for some other reason. These conditions can limit travel of the shift forks and prevent the synchronizers and mating gears from fully engaging. Linkage interference is often the cause if the problem occurs only when the vehicle is in a gear (high gear included) and accelerated.

If the linkage is all right, check for chipped or broken gear teeth. Defective teeth may be causing the problem. (Defective teeth may also be the result of something else that is causing the problem.) Check the splines on the synchronizers. Worn or damaged splines on the outer sleeve or inner hub could be causing slipout. Also, check the pilot bearing and front bearing retainer. A worn or damaged pilot bearing or a front bearing retainer that is broken or loose can cause enough gear movement to push the sleeve and gear apart.

If the transmission slips out of high gear *only*, begin by checking for loose bolts on the transmission, clutch housing, or engine mounts. A related cause is a misaligned transmission case or clutch housing. Other causes include worn linkage or binding shift linkage.

At times, jumpout and slipout problems can be corrected without removing the transmission. Often, problems with external shift linkage can be corrected by lubrication or adjustment. Sometimes, however, linkage parts are too worn to be corrected by adjustment and must be replaced. When the problem is caused by worn or damaged internal transmission parts, the transmission must be removed and disassembled.

Gear Clash

Gear clash is a grinding noise that is made while shifting gears. If a manual transmission develops gear clash, first check for improper clutch adjustment or a faulty clutch condition. The most common causes of gear clash are a clutch that drags or does not fully disengage. If the clutch is at fault, the clash should occur in every gear.

If the clutch checks out all right, or if the gear clash does not occur in all gears, check for worn transmission synchronizers, including sleeves, hubs, and blocking rings. Also, check for loose mounting bolts or misalignment, which sometimes causes gear clash.

Abnormal Noise

An **abnormal noise** in the manual transaxle is a noise above the normal sound level during operation, when in gear or in Neutral. Noises that are most noticeable may

sound like whining, rumbling, or roaring. The normal noise level may vary from gear to gear, depending on the gear ratio. Accelerating in low gear from a stop, for example, causes more noise than accelerating in direct drive at higher speeds.

Transmission noises can be difficult to separate from other vehicle noises. You should always make sure the problem is in the transmission. Other drive train noises are often blamed on the transmission. Be sure to eliminate the clutch, drive shaft assembly, and rear axle as possible causes of the problem. If the noise occurs only in one gear or in Neutral with the vehicle stopped (clutch pedal released), you can safely assume that the problem is in the transmission.

If the transmission is noisy in every gear and also in Neutral, first check for a low oil level. Another cause of noise in every gear and Neutral is a worn or damaged main drive gear or countershaft driven gear. A rumbling noise could come from a bad front bearing or bad countershaft needle bearings.

If the transmission is noisy in Neutral only, check for a damaged front bearing or damaged needle bearings in the countershaft gear assembly. If the transmission is noisy in high gear only, check for a damaged front or rear bearing or a damaged speedometer gear.

If the transmission is noisy in only one reduction or overdrive gear, check for wear or damage to the gearset parts that produce that particular gear. Another possible cause of noise is a set of worn needle bearings in the countershaft gear assembly.

A transmission that is noisy in Reverse only may have a worn or damaged idler gear, idler bushings, reverse countershaft gear, or mainshaft reverse gear. If the transmission has a first and reverse sliding gear, wear or damage to that gear may cause noise in Reverse and in First.

Some transmissions develop a clunking or slapping noise that is heard when the engine is accelerated or decelerated. This clunking noise is caused by excessive backlash, or play, in one or more gears. This can be confirmed by alternately accelerating and backing off in the affected gear. You should check for worn or missing thrust washers causing excessive shaft endplay, badly worn gears, worn or misaligned transmission bearings, or loose extension housing bolts. Be sure you have eliminated the clutch, universal joints, and rear axle assembly as sources of clunking before removing the transmission. Clunking noises are much more likely to be in other drive train parts than in the transmission.

Correcting most noises requires removing the transmission to gain access to defective gears or bearings. In some instances, such as with loose bolts or misalignment, the problem can be fixed without removing the transmission.



Note: An electronic stethoscope or listening device can help find the source of most noises. By attaching special clips to the transmission or other assembly, you can hear and pinpoint noises more easily.

In-Car Manual Transmission Service

Correcting some transmission problems does not require removing the transmission. For example, certain transmission leaks can be repaired without removing the transmission, including leaks at the side cover gasket, extension housing-to-case gasket, and rear seal. In some designs, shift forks can be replaced without removing the transmission, provided they are under an accessible cover assembly. Speedometer and cable assemblies can also be replaced without removing the transmission.

As covered in Chapter 8, floor-shift linkages can be either internal or external. Many modern floor-shift linkage systems are internal. This type has shift rails installed inside of the transmission. It seldom requires service. However, the external shift linkage is one area of the manual transmission that is vital to proper operation and that can be repaired without transmission removal, **Figure 9-3**. As parts wear, the motions of the gearshift lever are not correctly transferred to the transmission. Moving the shift lever may not shift the transmission into the desired gear.

The shift mechanism of the gearshift lever assembly may require adjustment or lubrication. Adjustment is usually accomplished by threaded swivels on the shift rods where they connect to the transmission shift levers. A shifter alignment tool is installed through holes in the shift levers and the shift mechanism during the adjustment process. The shift mechanism should be lubricated with water-resistant grease. The shift linkage rods and levers are relatively trouble free. Pivot bushings tend to wear out. When they do, they must be replaced.

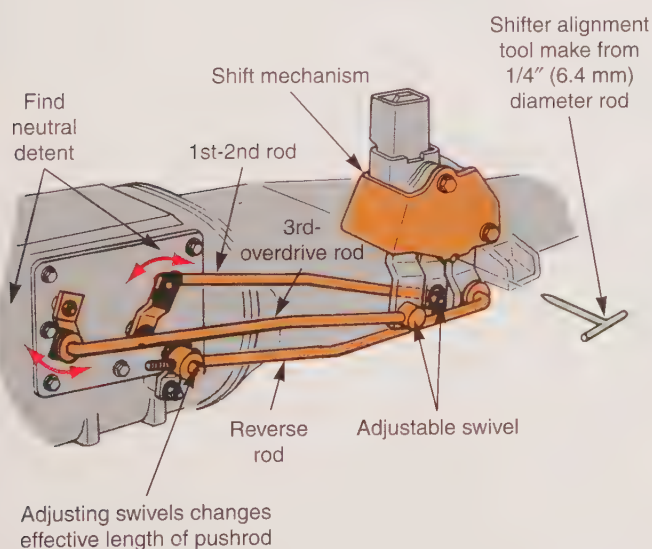


Figure 9-3. To adjust the external linkage, put the gearshift lever in Neutral. Secure the shift levers at the gearshift lever assembly with a shifter alignment tool. Adjust the shift rod length so the shift levers at the transmission are in the position marked by the Neutral detent. (Chrysler)

Manual Transmission Removal

This section covers the removal of manual transmissions. The information presented here is general in scope due to the number of different transmissions in use today. It is not intended as a substitute for the factory service manual.

As shown in **Figure 9-4**, manual transmissions contain many parts. To successfully complete the repair of a manual transmission, careful removal, disassembly, repair, reassembly, and installation are needed. Cleanliness and close inspection of parts are important at all stages of transmission repair.

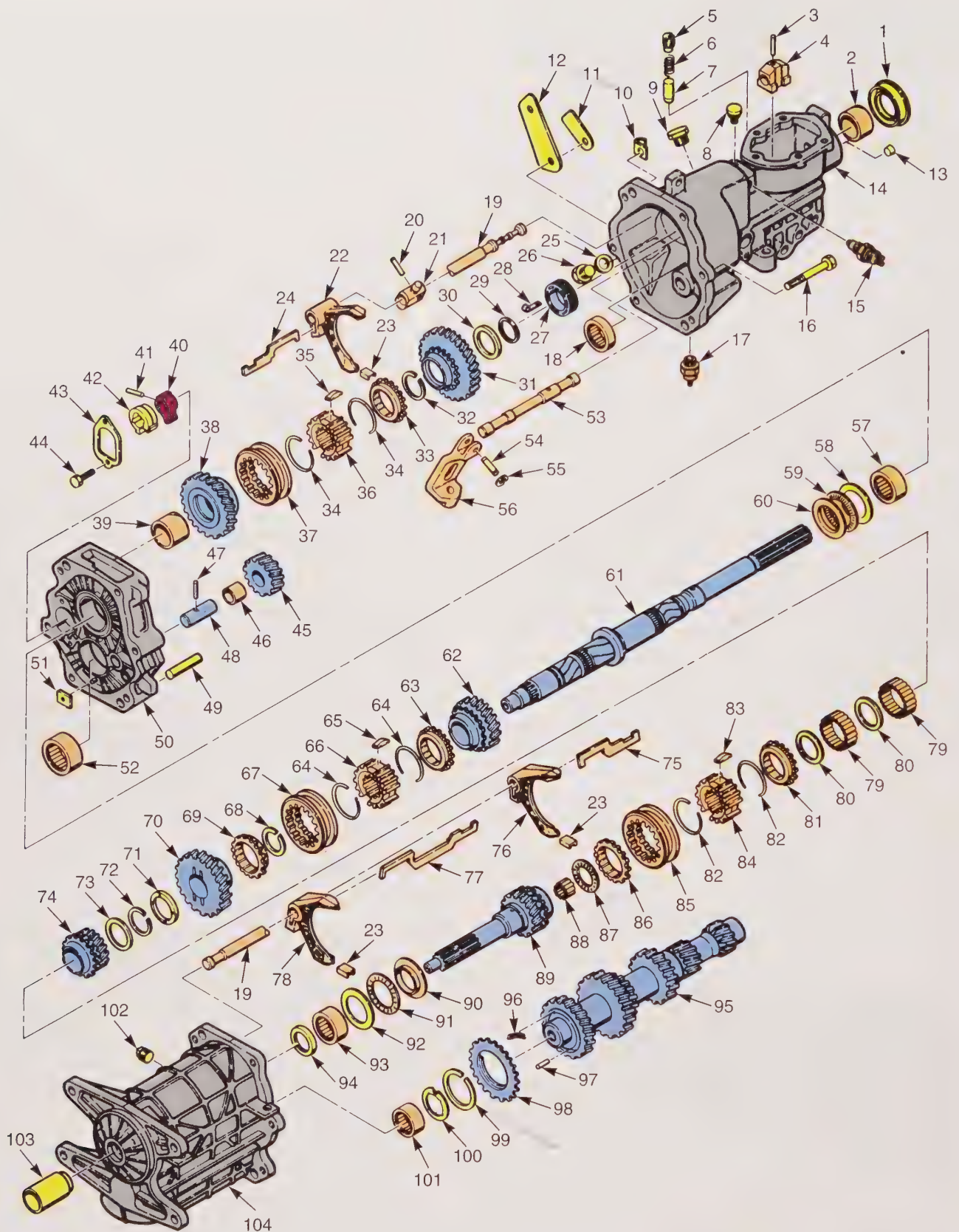
Before removing the transmission for service, try to determine the likely source of the transmission problem. A transmission that requires service does not always need to be removed, as discussed in the preceding section. However, if the source of the problem seems to be internal—defective gears, bearings, or shafts, for example—the transmission must come out of the vehicle.

Before performing any transmission service, you must identify the transmission. It is time-consuming and annoying to order parts or obtain service information for the wrong transmission. There are many kinds of manual transmissions, and they are difficult to identify by sight. Often, identical cases will contain different parts. You will usually need a transmission code number to determine exactly what kind of transmission is in the vehicle. Many transmissions have an identification tag attached to a cover bolt. If there is no tag, the vehicle identification number on the dash or door jam will often contain a transmission code letter. This tag or code letter will ensure that you get the right parts and information. The service information will explain the code number.

General Removal Procedures

The following general procedures detail how to remove a manual transmission from a vehicle. Usually, a manual transmission of a rear-wheel drive vehicle can be removed from underneath the vehicle without removing the engine. In a few instances, clearances are close and it is easier to remove the engine and transmission as a unit. This section assumes that the transmission can be removed without removing the engine. Note that you should always refer to the appropriate service information for specific procedures.

1. Disconnect the battery negative cable. This prevents accidental electrical shorts.
2. Place the transmission in neutral.
3. While under the hood, also remove the upper bellhousing attaching bolts (bellhousing-to-engine bolts), if the bellhousing is part of the transmission case. See **Figure 9-5**. In some cases, it may be necessary to install an engine holding fixture to support the weight of the engine once the rear engine mount is removed.



(continued)

Figure 9-4. This exploded view of a 5-speed transmission shows the many parts of a typical manual transmission. Note that this design has a center support. (General Motors)

Index No.	Description	Index No.	Description	Index No.	Description
1	Oil seal	36	Clutch hub	71	Thrust washer
2	Bushing	37	Clutch sleeve	72	Snap ring
3	Pin	38	Reverse gear & bushing assembly	73	Spacer
4	Shifter head	39	Bushing	74	5th Speed gear
5	Threaded plug	40	Selector arm	75	2nd & 3rd Shift link
6	Poppet spring	41	Spring pin	76	2nd & 3rd Shift fork
7	Mesh lock plunger	42	Interlock pawl	77	4th & 5th Shift link
8	Breather	43	Retaining plate	78	4th & 5th Shift fork
9	Selector lever pilot	44	1/4-20 × 3/4 Hex head self tapping screw	79	Needle rollers
10	Wiring harness clip	45	Reverse idler gear & bushing	80	Spacer
11	Name plate	46	Bushing	81	Synchronizer blocking ring
12	Back-up light bracket	47	Spring pin	82	Synchronizer spring
13	Cup plug	48	Reverse idler shaft	83	Shift plate
14	Extension housing	49	Dowel pin	84	Clutch hub
15	Switch	50	Center support	85	Clutch sleeve
16	3/8-16 × 3-1/4 Hex head bolt	51	Magnet	86	Synchronizer blocking ring
17	Switch	52	Needle bearing	87	Needle thrust bearing
18	Needle bearing	53	Shift rail	88	Needle rollers
19	Shift rail	54	Pin	89	Input drive gear
20	Spring pin	55	Retaining clip	90	Needle thrust plate
21	Rail selector	56	Selector lever	91	Needle thrust bearing
22	First & reverse shift fork	57	Needle bearing	92	Thrust washer
23	Shift fork pad	58	Thrust washer	93	Needle bearing
24	First & reverse shift link	59	Needle thrust bearing	94	Oil seal
25	Gasket	60	Needle thrust race	95	Cluster gear
26	9/16-18 Plug	61	Output shaft	96	Spring
27	Speedometer gear	62	3rd Speed gear	97	Spring pin
28	Speedometer gear retainer	63	Blocking ring	98	Gear damper
29	Snap ring	64	Synchronizer spring	99	Snap ring
30	Thrust washer	65	Synchronizer shift plate	100	Thrust washer
31	1st Speed gear	66	Clutch hub	101	Needle bearing
32	Snap ring	67	Clutch sleeve	102	1-2 Inch pipe plug
33	Blocking ring	68	Snap ring	103	Transmission case sleeve
34	Synchronizer spring	69	Synchronizer blocking ring	104	Transmission case
35	Shift plate	70	2nd Speed gear		

Figure 9-4. (continued)

- Raise the vehicle on a hydraulic lift to get enough clearance to remove the transmission. If you do not have access to a hydraulic lift, always use a good quality hydraulic floor jack and approved jack stands.



Warning: Never support the vehicle with wooden crates or cement blocks. Be sure the vehicle is secure before working underneath it.

- Check the engine mounts to ensure they are not broken, which could be the cause of shifting or clutch problems.



Warning: Broken engine mounts can allow the engine to fall backwards once the transmission crossmember, which provides support for the transmission, has been removed.

- Drain the transmission oil. **Figure 9-6** shows the location of the drain and fill plugs on a typical transmission. It is not absolutely necessary to drain the oil, as a drain plug may not be provided. However, a full transmission will leak oil when the drive shaft assembly or other parts are removed. Be ready with a drip pan to catch spilled gear oil.

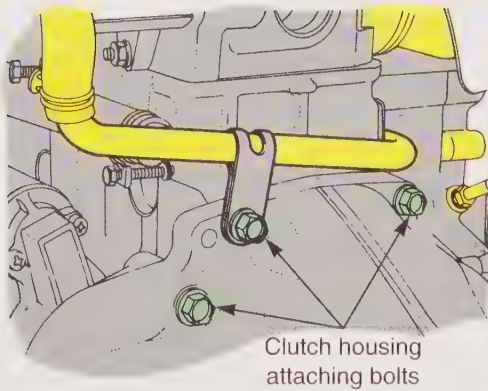


Figure 9-5. As part of the transmission removal procedure, remove the upper bellhousing attaching bolts while the vehicle is still on the ground. (Chrysler)

7. Mark the drive shaft assembly at the rear axle assembly so that it can be reinstalled in the same position. (See Chapter 13 for more information on drive shaft assembly removal.) Remove the bolts from the rear of the drive shaft assembly and slip the drive shaft out of the extension housing. Once the drive shaft assembly is out, plug the rear of the extension housing to reduce oil leakage.
8. If the bellhousing is part of the transmission case, remove the lower access cover, disconnect the clutch linkage at the clutch fork, and remove the starter (if bolted to the clutch housing).
9. If the vehicle has an external shift linkage, disconnect it at this time. This procedure will vary with the make of transmission. In general, disconnect the shift rods from the shift levers at the transmission case. If an external floor-shift linkage is used, also unbolt the gearshift lever assembly from the case or extension housing. Remove the assembly, pulling the gearshift lever through the hole in the floor pan in the process. Removing the assembly will make for easier handling of the transmission.

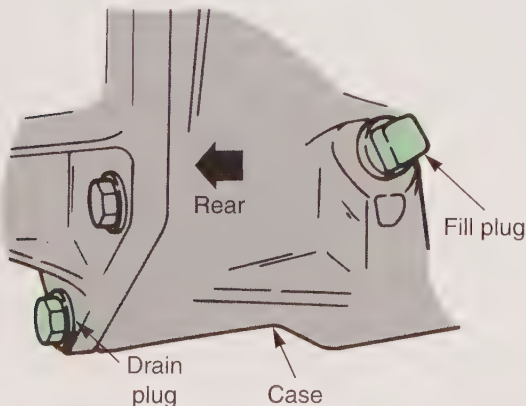


Figure 9-6. As part of the transmission removal procedure, drain the oil through the drain plug or through a bolt hole low on the transmission case. (General Motors)

10. Remove other miscellaneous items connected to the transmission, such as the speedometer cable assembly. If the transmission has any electrical connections, remove the connectors now. Label the connectors, using masking tape, to simplify reconnection, and place them out of the way.
11. On many vehicles, especially those with V6 or V8 engines, it may be necessary to remove the exhaust pipes. This will give you more clearance when the transmission is removed. Removing the exhaust pipes also allows you to lower the back of the engine, which may be required to reach some of the bellhousing attaching bolts.
12. Disconnect any hardware attached to the transmission crossmember, such as the parking brake linkage. Removing the linkage will relieve pressure on the crossmember caused by the parking brake return spring and will give more clearance.
13. If an engine holding fixture is not already in place, support the engine with a jack placed under the rear of the engine or clutch housing (where separate from transmission).



Warning: Never let the engine hang suspended only by the front engine mounts. Failure to support the engine before removing the transmission can result in serious injury.

14. Place a transmission jack (or floor jack) under the transmission. Raise the transmission slightly to remove weight from the crossmember. Then, remove the fasteners holding the crossmember to the vehicle frame and to the transmission, or rear engine, mount. Remove the crossmember.



Caution: If you are using a standard floor jack instead of a transmission jack, place a block of wood between the jack pad and the transmission case to reduce movement and possible damage to the case. See Figure 9-7.

15. If the bellhousing and case are a one-piece design, remove the remaining bellhousing attaching bolts, which hold the bellhousing to the engine. You may need to tilt the engine and transmission back slightly to access the bolts. If the bellhousing and transmission case are separate castings, remove the transmission case attaching bolts (transmission case-to-bellhousing bolts). Most transmissions will have four bolts, one at each corner.

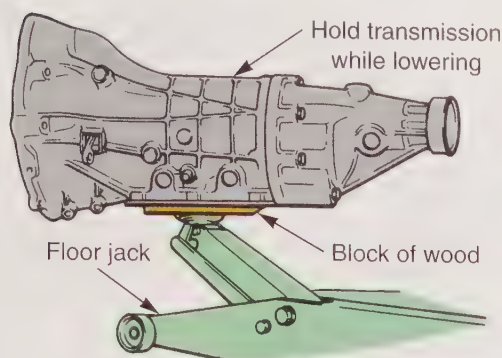


Figure 9-7. Use a transmission jack or a floor jack to support and remove the transmission. When using a floor jack, place a block of wood between the jack pad and the transmission case. Move the transmission to the workbench with the jack lowered. (Chrysler)



Warning: A manual transmission is heavy. Use the transmission jack to support and lower the transmission.

Also, do *not* let the transmission hang unsupported once the bellhousing or transmission case attaching bolts are removed. This can damage the clutch, disc hub, or transmission input shaft. Always leave at least two attaching bolts in place until you have a jack under the transmission.

16. Slide the transmission straight back until the input shaft clears the clutch assembly or bellhousing as required. In the process, raise or lower the transmission jack until there is no binding between the splines on the input shaft and the clutch disc hub. When the input shaft is clear of the clutch assembly or bellhousing, lower the transmission. Watch clearances and watch for any component you may have forgotten to disconnect. Transport the transmission to the workbench with the jack in the lowered position.

Manual Transmission Disassembly

Once the transmission is removed from the vehicle, it can be disassembled for cleaning, inspection, and repair. The procedure outlined here is general and does not specifically cover any one transmission. You should always consult the appropriate service information for exact disassembly procedures and specifications.

As you disassemble the transmission, carefully note the position of all parts and lay parts down on the workbench in the same sequence as removed. This will make reassembly easier. If necessary, index mating parts with light punch marks to ensure proper reassembly.

Removing External Components

The first step in disassembling a transmission is to remove the external components. If the gearshift lever assembly has not yet been removed, remove it now, **Figure 9-8**. If the transmission has an access cover, it should be removed, **Figure 9-9A**. Once the access cover has been removed, the transmission internals can be inspected for obvious damage. See **Figure 9-9B**.

It is a good practice to observe transmission action with the cover removed. Inspect the operation of the shift forks and the internal shift linkage. If the shift forks were not removed with the access cover, shift the transmission into each gear by actuating the shift forks. At the same time, rotate the input shaft while inspecting the condition of the gears and the synchronizers. Doing this, you can observe any operating defects in the gears, the synchronizers, and the internal parts of the shift linkage.

To proceed with the disassembly, mark the case and front bearing retainer, as shown in **Figure 9-10**. These alignment marks will be used during reassembly to install the retainer in its original position. This step ensures proper operation, although it may seem minor.

If the bellhousing is a one-piece unit with the case, the throwout bearing and clutch fork will have come out of the vehicle with the transmission, and the bearing will still be on the hub of the front bearing retainer. Remove the clutch fork at this time. Most clutch forks can be pulled from the ball stud and removed through the fork opening in the bellhousing. Once the clutch fork is removed, slide the throwout bearing from the bearing retainer hub. Then, unbolt the retainer and remove it by slipping it off the input shaft. Remove the front bearing retainer seal from its seat within the retainer, **Figure 9-11**.

After the retainer has been removed, the transmission front bearing should be removed. Some bearings must be removed with a manufacturer specific puller, **Figure 9-12**.

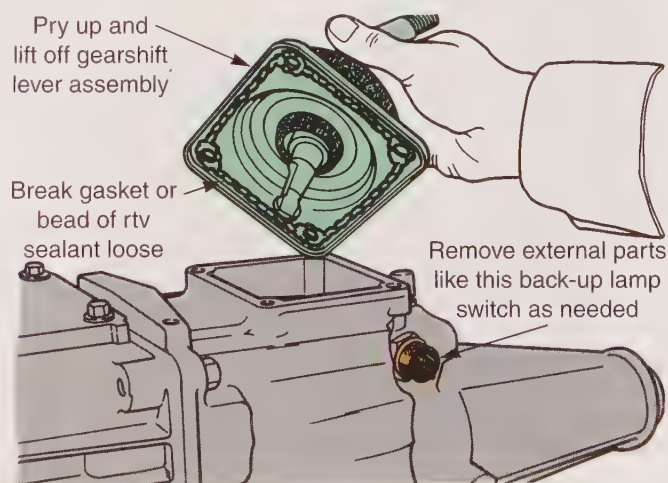


Figure 9-8. This shows the removal of the gearshift lever assembly from the transmission extension housing. Other external parts may also require removal. (Chrysler)

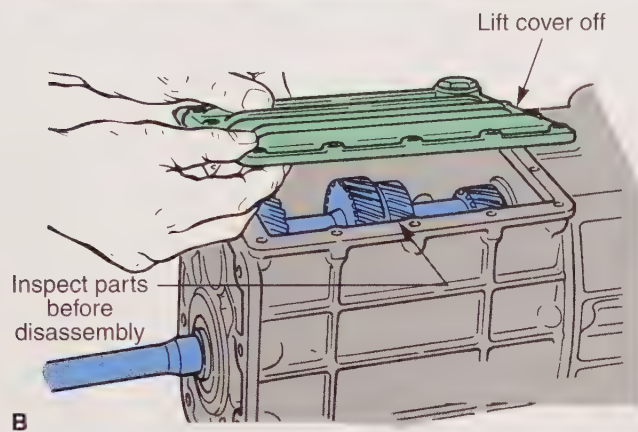
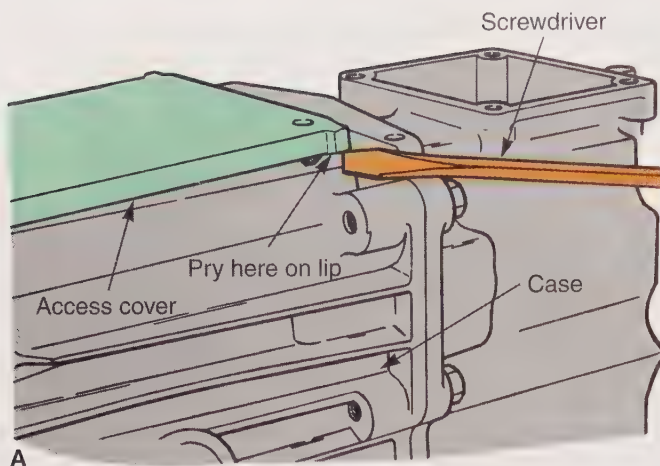


Figure 9-9. Removing the access cover from the transmission case. A—If necessary, the cover can be removed by lightly prying on it with a screwdriver. B—You should inspect the internal parts for obvious problems before removing them. If shift forks are not removed with the access cover, actuate them while turning the input shaft. Observe the transmission's operation through the access cover opening. (Chrysler, Ford)

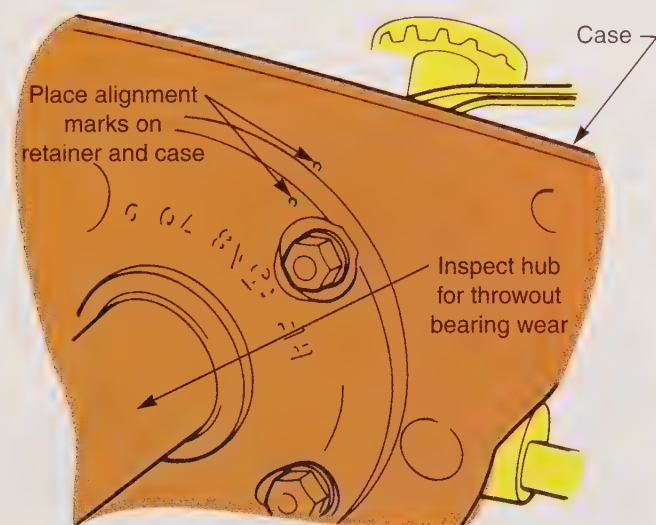


Figure 9-10. Unbolt the front bearing retainer from the transmission case, but always mark the case and bearing retainer first. Slip the retainer over the input shaft. The retainer hub should be inspected for wear caused by the throwout bearing. (General Motors)

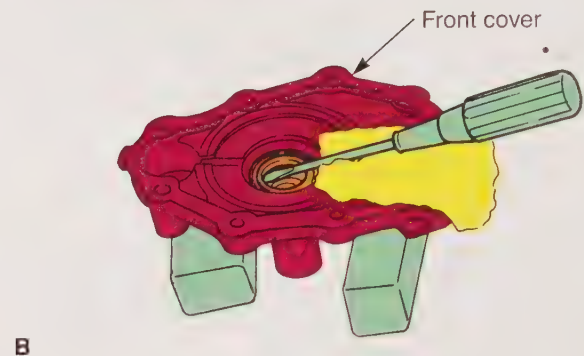
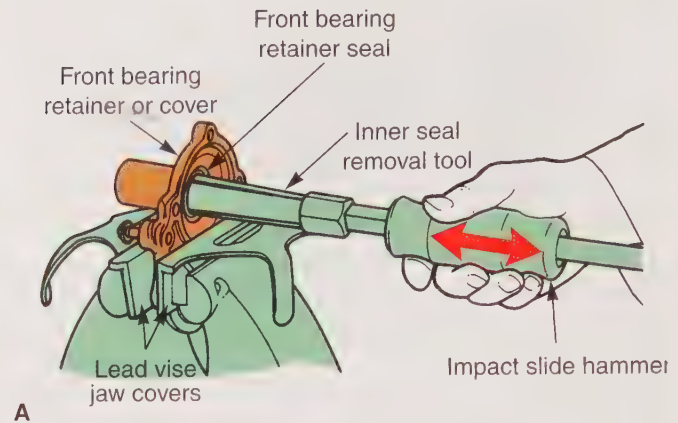


Figure 9-11. Removing the front bearing retainer seal. A—Some seals must be removed with a special puller. B—Some seals can be pried loose with a screwdriver. (Ford, Nissan)

Once the bearing is out, the input shaft can usually be removed. However, some input shafts cannot be removed until the mainshaft is out.

Next, remove any external components that would prevent or would otherwise be damaged by extension housing removal, which is the following step. **Figure 9-13** shows a shift rail detent ball assembly that would be damaged if it were not removed before the extension housing. The speedometer assembly should also be removed if it was not taken out during transmission

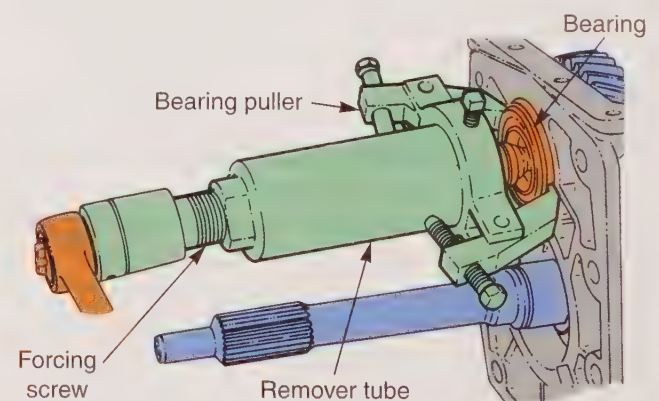


Figure 9-12. Some bearings must be removed with a bearing puller, as shown here. Other bearings can be removed by removing a large snap ring and then prying the bearing from the case. Note that the bearing puller shown is being used to remove a countershaft bearing. (Ford)

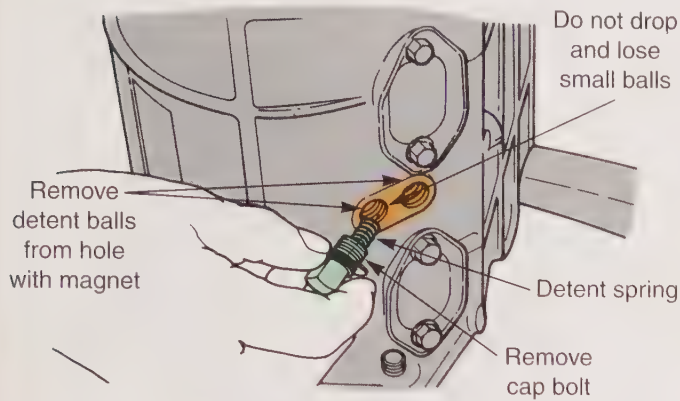


Figure 9-13. Some external parts, such as the detent ball assemblies shown here, must be removed before the extension housing is removed from the transmission case. (Ford)

removal. Most speedometer assemblies are held to the case by a single bolt.

After all such components are removed, the extension housing should be removed from the transmission case. To do this, remove the extension housing bolts and break the gasket seal by tapping on the housing with a soft mallet, **Figure 9-14**. It may be necessary to pry on the housing to break the gasket seal.

Removing Internal Components

Before removing the internal components, measure gear endplay to check for wear. To do this, use a feeler gauge and measure the clearance between each mainshaft gear, **Figure 9-15**. The standard endplay is listed in the specifications. If the endplay is out of spec, look for excessive wear on the sides of the gears or thrust washers once the shaft is disassembled. Replace these components as necessary.

To begin removing internal parts, you must often remove the snap rings that hold gears to their shafts or that hold bearings in their case. **Figure 9-16** shows a snap ring being removed with a pair of snap ring pliers.

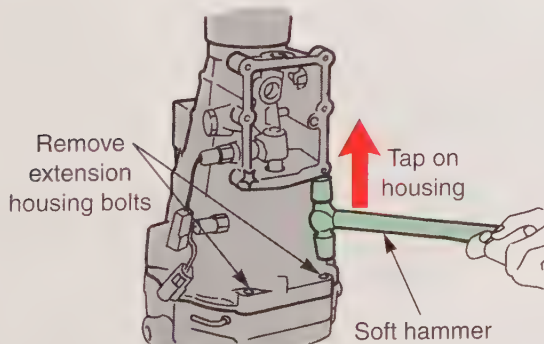


Figure 9-14. Before removing the extension housing from the transmission case, remove the bolts and loosen the extension housing by tapping with a soft mallet. (Nissan)

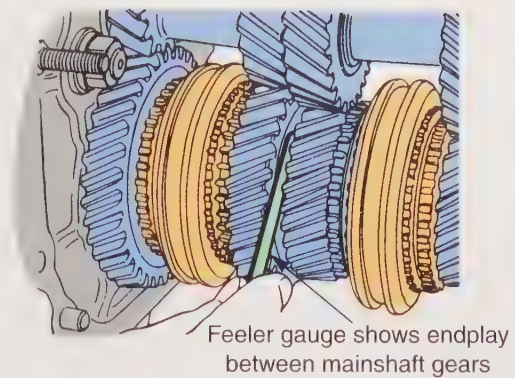


Figure 9-15. Feeler gauges can be used to check the clearance between gears, as shown here. (Subaru)

If the internal parts of the shift linkage and the shift forks were not installed in the access cover, they should be removed from the case now. First, mark shift forks and rails with a punch, **Figure 9-17**. These alignment marks will be used during reassembly to install the parts in their original position. To remove the forks, drive the roll pins from the shift forks and rails. See **Figure 9-18**.

Next, remove the gears inside the case. If the transmission case is a two-piece type, such as that shown in **Figure 9-19**, the gears and shafts can be lifted out of the case once the case halves are split. Note that a transmission with this type of case may be referred to as a **split-case transmission**.

The gears and shafts of most transmissions with one-piece cases must be removed through a series of steps. Again, the procedure will vary with the type of transmission, and you should consult the appropriate service information for the exact removal sequence.

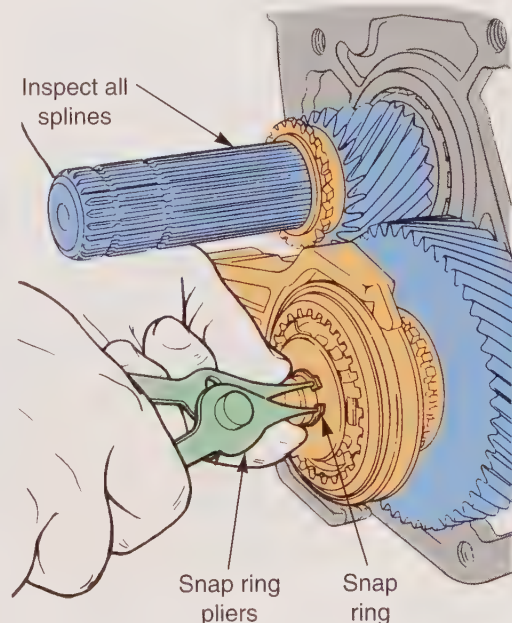


Figure 9-16. Many gears and bearings cannot be removed from the shaft without first removing a snap ring. Once the ring is removed, the part will slide from the shaft. (General Motors)

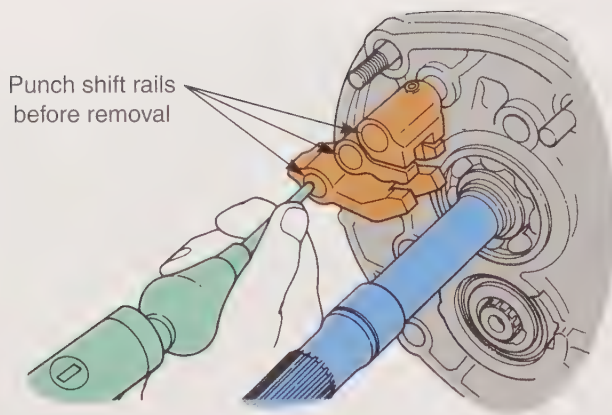


Figure 9-17. Shift rails (and forks) must be marked before removal. If this is not done, they might get installed in the wrong position. (Ford)

With some transmission cases, individual gears must be removed from the shaft before the shaft itself can be removed, **Figure 9-20**. Once the necessary gears and bearings have been removed, the entire mainshaft gear assembly can be removed from the case. See **Figure 9-21**. Be aware that loose mainshaft (and countershaft) needle bearings and thrust washers will fall into the transmission case as the shafts are removed. Retrieve all small parts as soon as possible!

After the mainshaft is out of the way, the countershaft gear assembly can be removed by first removing the countershaft. Some countershafts are held in place by special keys, which must be removed before the shaft can be driven from the case. Usually, the shaft is driven from

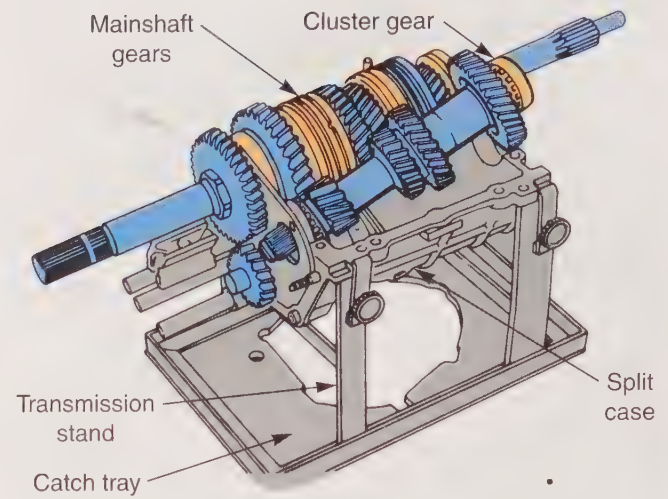


Figure 9-19. A split-case transmission is shown being held on a stand. The top half of the case has been removed. Removing parts from a split-case transmission is easy. The case is opened up, and the parts are simply lifted out. Most transmissions are not this easy to disassemble. (Chrysler)

the case using a soft hammer and a dummy shaft. Once the countershaft is out, the cluster gear is simply removed from the case.

Note that a **dummy shaft** can be made from a piece of wood. A broomstick or wooden dowel works well. The dummy shaft should be cut to the same length as the cluster gear. The shaft allows you to remove the cluster gear without dislodging the needle bearings from position in their bearing bores.

Also note that with some one-piece transmissions, the countershaft must be removed before the mainshaft gear assembly. In such designs, removing the countershaft first allows the countershaft gear to drop down far enough that the mainshaft can be removed from the case.

To remove the reverse idler gear, remove the reverse idler shaft retainer key and pull the shaft from the case. Some shafts do not have a key. Remove the needle bearings and thrust washers also.

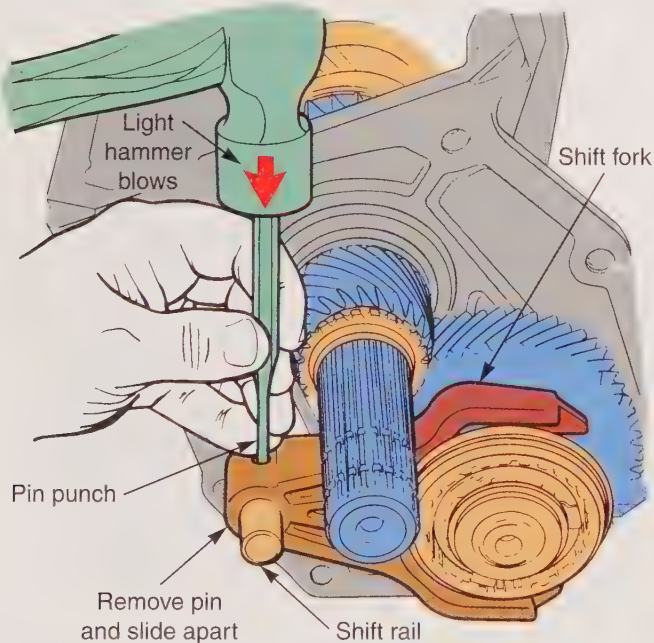


Figure 9-18. This shift fork is removed by driving out the roll pin, which holds it to the shift rail. Be careful not to lose the pin. (General Motors)

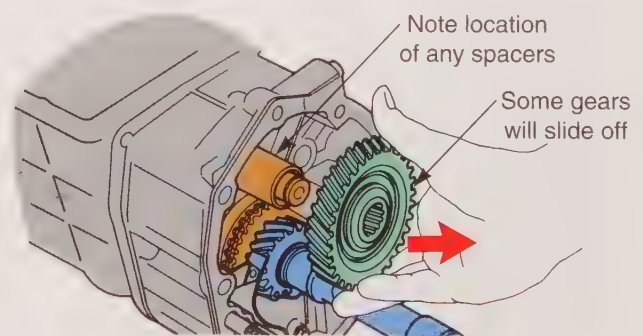


Figure 9-20. To remove some transmission shafts, it is often necessary to remove individual gears from the shaft. With these gears removed, the shaft can be lifted from the transmission case. Some shafts will slide through an opening in the case after a large gear has been removed. (Ford)

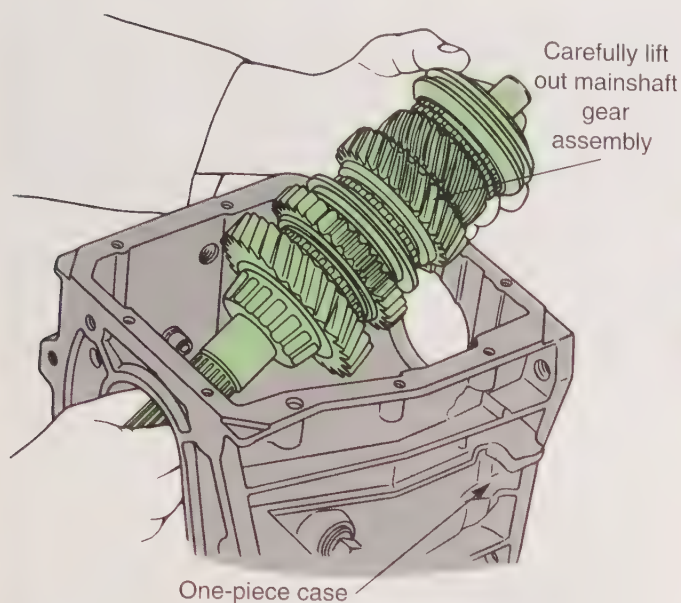


Figure 9-21. This mainshaft gear assembly is pulled out through the opening at the top of this one-piece transmission case. Some mainshafts are removed through the rear. (General Motors)

If the input shaft and main drive gear have not yet been removed, remove any snap rings that hold the front bearing to the transmission case. Then, remove the input shaft and bearing from the case. The bearing may be tight in the case. A light tap on the shaft with a soft hammer should free it.

Disassembling the Components

The next step involved in disassembly is to take apart the components that were removed from the transmission case. After the parts are disassembled, you will need to inspect them. However, it is also important that you examine the parts as they come apart. See **Figure 9-22**.

To disassemble the mainshaft gear assembly, remove the snap ring from the front end of the output shaft. Then, slide the synchronizers and mainshaft gears off the front end. Remove the other snap rings along the output shaft so that all gears and synchronizers can be removed. In a few instances, gears and synchronizers must be pressed from the shaft. **Figure 9-23** illustrates a technique that can be used for removing a snap ring. **Figure 9-24** shows a mainshaft gear and synchronizer being removed from the output shaft.

Shift linkage, if mounted in an access cover, will require disassembly, as will any bearings that were not removed in previous steps. Seals that are still in place should be removed from their components now. Most seals can be pried from their housings with a screwdriver.

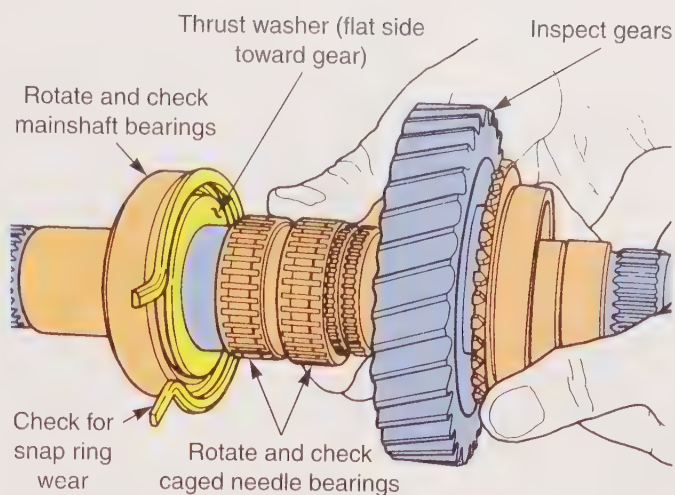


Figure 9-22. Parts are inspected after they are disassembled, but they should also be checked before the assemblies come apart. The parts on this mainshaft are being checked for rotation. (Chrysler)

and damage. This includes all moving and stationary parts, since almost any transmission part can be defective in some way.

Begin by thoroughly cleaning the transmission case and all other parts with solvent. When cleaning the case, make sure you do not lose any parts, such as needle bearings that may have fallen to the bottom of the case.

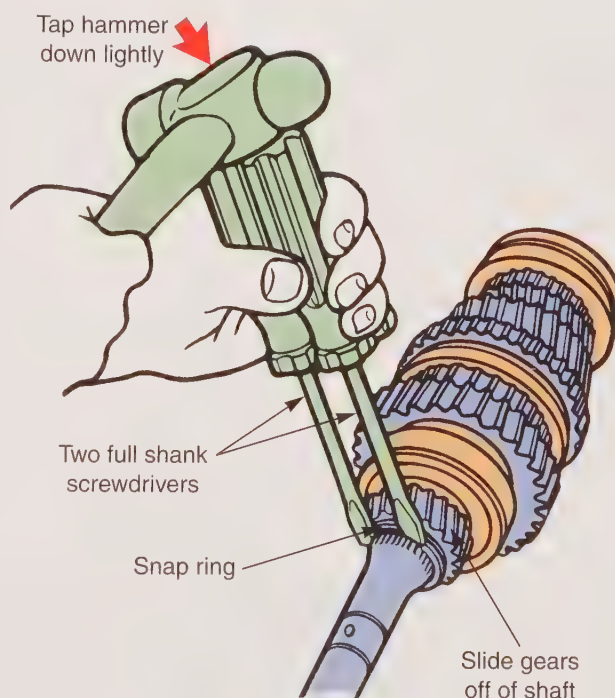


Figure 9-23. This shows a fifth gear snap ring being removed from the output shaft. This method of removing a snap ring can be substituted for using snap ring pliers. After the snap ring is removed, the gears will often slide from the shaft. Be sure to wear eye protection when removing snap rings! (Chrysler)

Manual Transmission Parts Inspection

Before ordering parts or beginning reassembly, thoroughly check the transmission components for wear

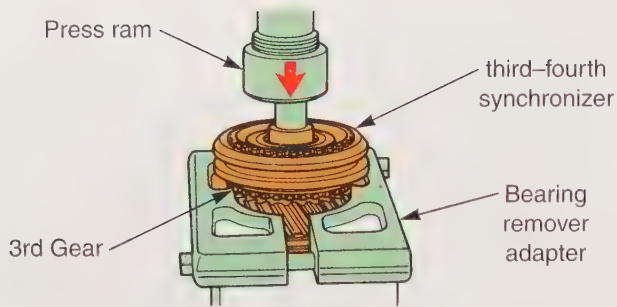


Figure 9-24. Some parts must be disassembled with a press. This shows the third gear and the third-fourth synchronizer being pressed from the output shaft. Do not attempt to hammer the parts from the shaft. (Ford)

Clean the bearings thoroughly, but do *not* spin the encased bearings with compressed air. Parts that are cleaned with water should be thoroughly dried and, then, lightly oiled. You should also check related parts that may or may not have been removed with the transmission. The shift linkage, clutch, and drive shaft assembly universal joints may require servicing.

Visual Inspection

Much of parts inspection is looking for obvious damage by visual examination. Check the synchronizer hubs and sleeves for worn or broken teeth, **Figure 9-25**. Check the grooves in the outer sleeves where the shift forks ride. Also, check the shift forks for wear or distortion. Check the blocking rings for wear on the outer gear teeth and on the tapered ring surfaces that contact the gear cone surface. See **Figure 9-26**. Worn or damaged parts should be replaced.

Look for signs of gear damage, such as worn, cracked, or chipped gear teeth, **Figure 9-27**. If any teeth are defective, the gear should be replaced.

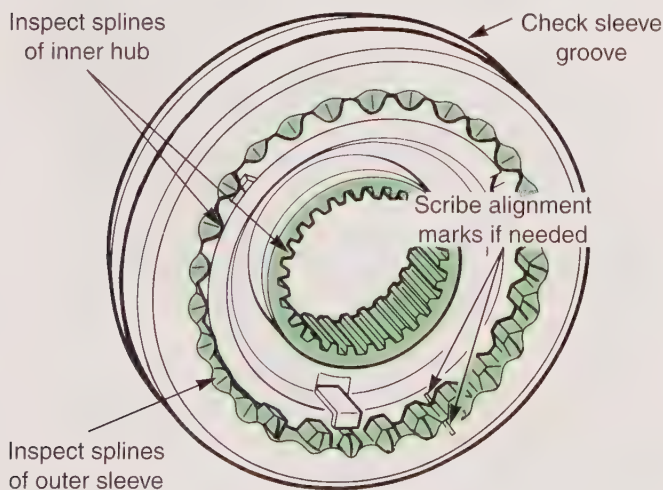
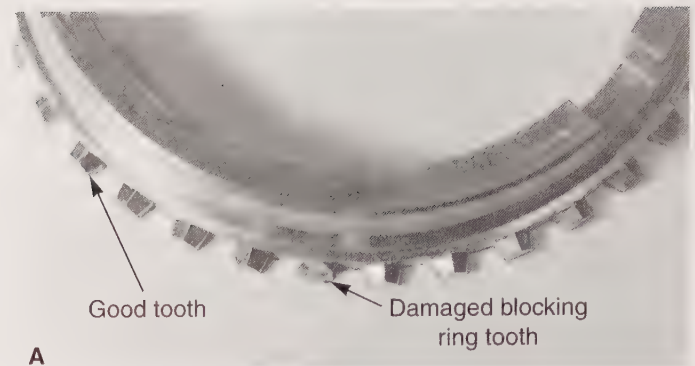


Figure 9-25. The synchronizer hub and sleeve should be carefully checked for wear and damage. Defective synchronizers will cause gear clash, hard shifting, or gear slipout. (General Motors)



A



B

Figure 9-26. Conduct visual checks of synchronizer blocking rings. A—Look for worn or broken teeth. B—Inspect the fine ridges in the tapered surface. Edges should be sharp.

Also, inspect the bushings pressed into the gear surfaces. Worn bushings can usually be replaced. However, for some gears, replacement bushings cannot be obtained and the entire gear must be replaced. Check for wear

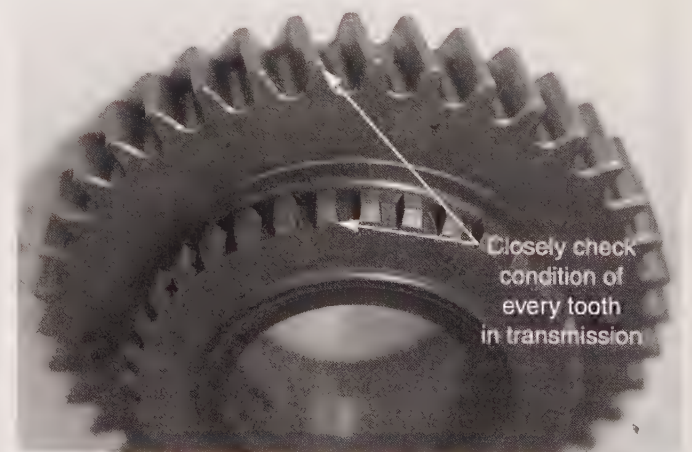


Figure 9-27. All parts should be cleaned and inspected before reassembly. This gear shows signs of wear on both sets of teeth.

between each gear and the machined area, or race, it fits over on the shaft. If a gear can be rocked on its shaft, the bushing, the gear, or possibly the shaft will need to be replaced.

Thrust washers should be checked for wear and scoring. Also, check snap rings and snap ring grooves for wear or damage. Badly bent snap rings should be replaced. **Figure 9-28** shows the parts of a gear and shaft assembly that should be inspected.

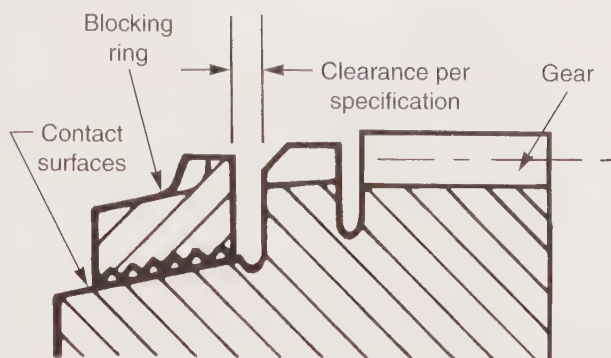
Closely examine all bearings, looking for signs of wear. Ball bearings and roller bearings can be checked by rotating them by hand. If you feel any roughness when turning a clean bearing, the bearing should be replaced. Caged roller bearings can be checked by turning them on their mating bushings. Loose, or uncaged, needle bearings should be checked for flat spots. Bearings with flat spots must be replaced.

The transmission case and all other stationary parts should be checked for cracks, which can cause lubricant leaks. Also, look for any kind of distortion, which can cause misalignment of the moving parts or poor sealing surfaces. Inspect the front bearing retainer hub for wear caused by the throwout bearing. While you are at it, check the clutch fork, ball stud (if applicable), and throwout bearing for wear.

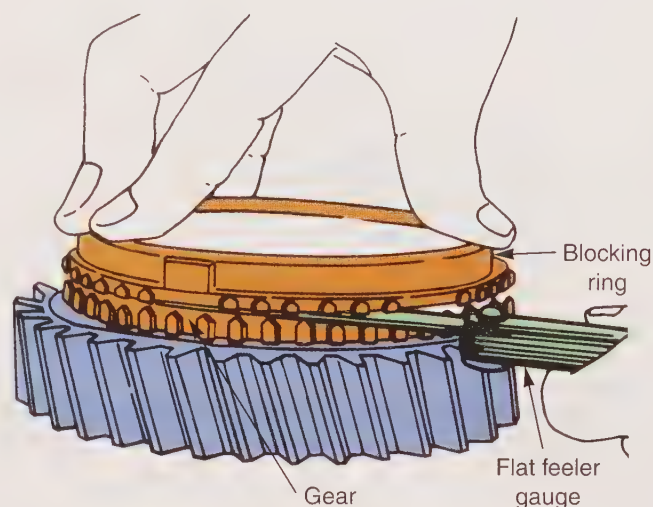
Measurement Inspection

Some transmission parts should be checked with special measuring instruments. Use of feeler gauges, micrometers, calipers, and dial indicators can help to identify defective parts that would otherwise be unnoticed. They can help ensure a good repair job. Specific measuring instruments mentioned here were covered in detail in Chapter 3.

Blocking rings must maintain a certain clearance between the ring itself and the straight-cut teeth of the mating gear, **Figure 9-29A**. The ridged surface of the blocking ring is worn if the clearance is too small and the ring has moved too far into the cone surface of the mating gear. To measure the clearance, a flat feeler gauge may be used as shown in **Figure 9-29B**.



A



B

Figure 9-29. Inspecting blocking ring for wear. A—Sectional view shows clearance between blocking ring and mating gear. If the ring moves too far into the mating cone surface, the tapered surface of the blocking ring is worn. B—A flat feeler gauge can be used to measure clearance between the mating parts. (Ford)

Some transmissions have a clearance specification for the inserts and insert slots of the synchronizer inner hub, **Figure 9-30**. The sliding caliper is used to take the inside measurement of the hub slot and the outside measurement of the insert. The difference between the two measurements is the clearance. If the clearance is excessive, all parts should be replaced.

Some manual transmission manufacturers provide a clearance measurement between the shift fork and the shift fork groove in the outer sleeve of the synchronizer. This clearance can be measured with a feeler gauge. See **Figure 9-31**.

Another item to check is the amount of backlash between two gears. This can be checked with a feeler gauge between the teeth or with a dial indicator. Excessive backlash usually means that both gears (or their bushings) are worn and should be replaced.

Other items to check are illustrated in **Figure 9-32**. A micrometer can be used to check the outside diameters of shafts and bushings. This is useful for determining wear on these parts. A sliding caliper can be used to check the

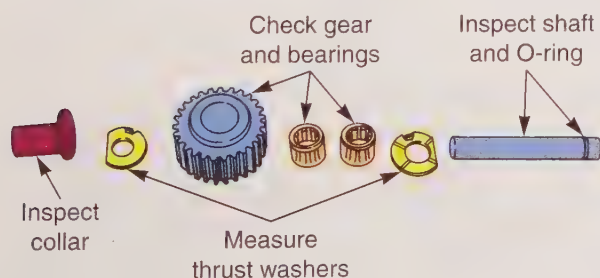


Figure 9-28. These are typical parts that must be inspected during disassembly. Although the idler gear, shown here, is only used in reverse, it can wear out or become damaged. You should inspect all parts of the idler gear assembly and other gear assemblies.

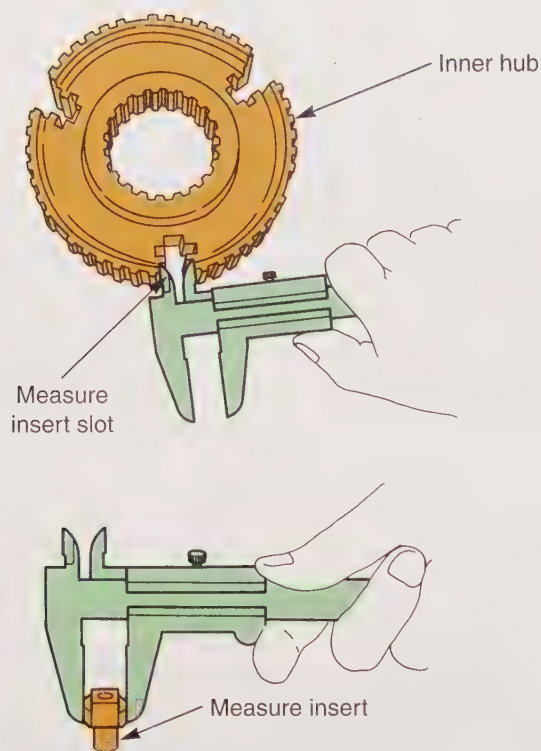


Figure 9-30. Some manufacturers specify a clearance between the inner hub slots and the inserts. A sliding caliper, which can measure inside and outside dimensions, is used in determining this distance.

thickness of a flange, which is often done to determine the need for thicker thrust washers. Finally, a dial indicator is useful for checking shaft runout.

Some stationary parts also require measurements. **Figure 9-33** shows a depth micrometer being used to check the bearing bore depth of an aluminum housing. This measurement has a direct effect on the amount of endplay of the transmission mainshaft. The measurement (and endplay) can be controlled by special shims placed at the bottom of the bearing bore.

Manual Transmission Assembly

This section will give general details of manual transmission assembly. Before beginning the assembly of the transmission, make sure you have the correct replacement parts by matching them against the old parts. Also, lightly lubricate each transmission part with the proper lubricant.

Assembling the Components

The first step in transmission assembly is to assemble all the transmission subassemblies. If the transmission uses case-mounted shift forks or rails, in many (but not all) instances, they should be reinstalled now. See **Figure 9-34**. This step will not apply where the shift linkage is mounted in a top or side access cover.

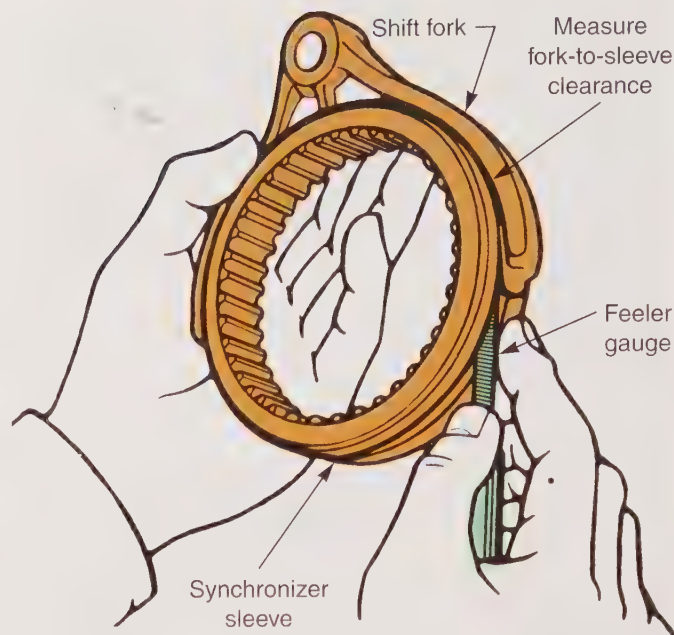


Figure 9-31. Clearance between the outer sleeve and the shift fork can be checked with a feeler gauge. Note if the shift fork has nylon inserts (where the fork contacts the sleeve). Inserts should be replaced when the transmission is serviced. (Chrysler)

Assemble the synchronizers, **Figure 9-35**, and ensure that they operate properly. Then, assemble the gears, synchronizers, and bearings on the mainshaft, **Figure 9-36**. Sometimes, gears cannot be installed until after the mainshaft is installed in the transmission case. See **Figure 9-37**.

During the assembly process, make sure the snap rings fit snugly in their grooves. If not, they will allow movement of parts on the shaft or may even pop out of their groove. **Figure 9-38** shows a simple check of a snap ring in its groove. For a more exact check, a feeler gauge should be used to measure the clearance between the ring and groove. The measurement is checked against the specifications to see that the maximum groove clearance is not exceeded. If it is, the snap ring is not wide enough. Replacement snap rings are available in varying thicknesses.

After all the components are installed in the proper order, install the final snap ring on the end of the mainshaft. Then, check that all parts turn freely.

If the mainshaft pilot needle bearings are uncaged, they can be reinstalled in the bore behind the main drive gear, as shown in **Figure 9-39**. Use heavy grease to hold them in place. Once this is done, set the input shaft aside.

If needle bearings are used in the countershaft gear assembly, position them in the bearing bores at each end of the cluster gear. Use heavy grease and a dummy shaft to hold the needle bearings in place. The dummy shaft will allow you to install the cluster gear in the transmission case without dislodging the needle bearings.

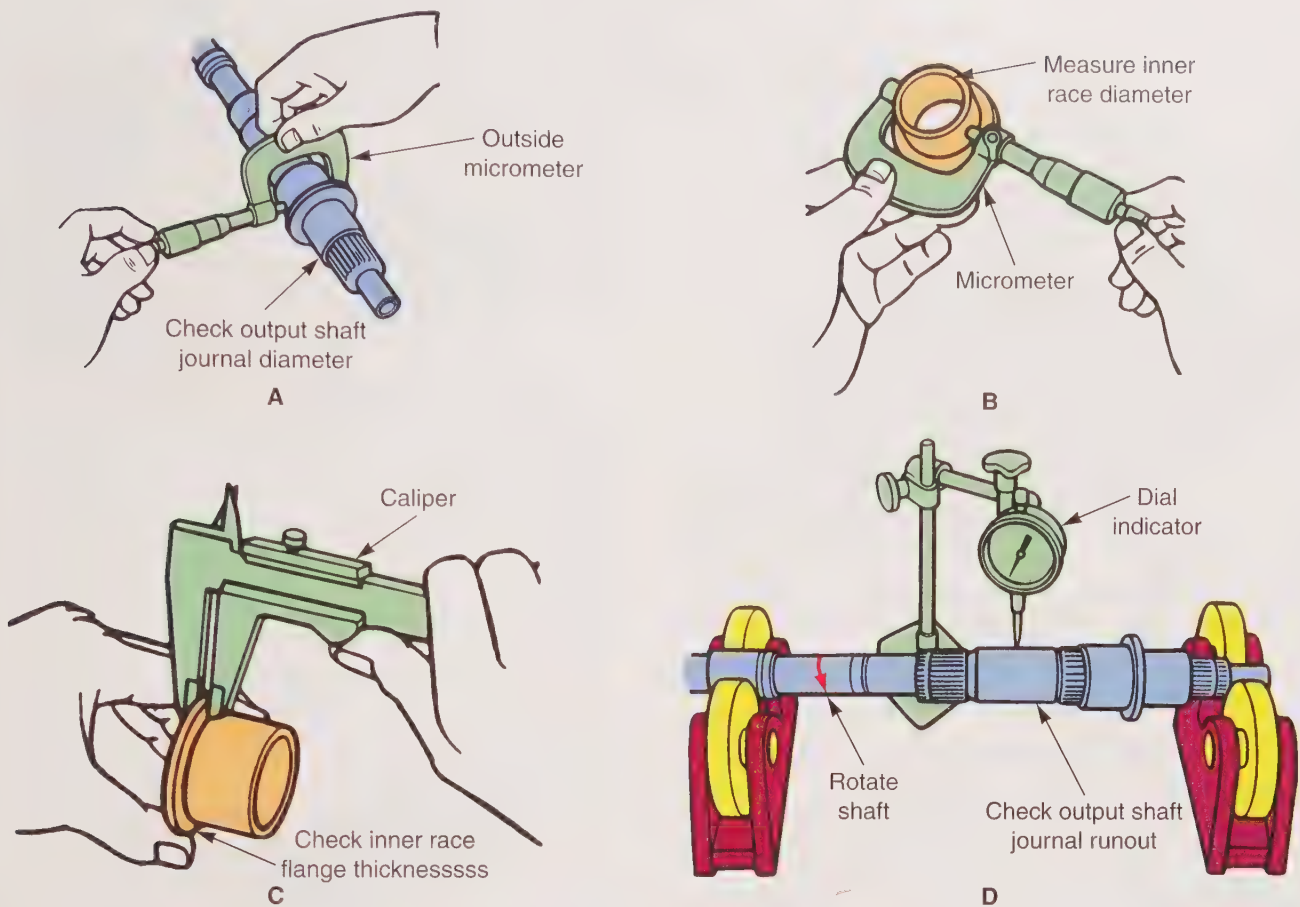


Figure 9-32. Various instruments are used to check different transmission parts. A—Micrometers can be used to check the outside diameters of shafts. If the shaft has worn until it is undersized, it must be replaced. B—The micrometer can also be used to check a bushing. A worn bushing should also be replaced. C—A sliding caliper can be used to check the thickness of a flange. The thickness of this flange will affect endplay and the fit of the gears and bearings on a shaft. Thrust washers can also be checked with calipers. D—A dial indicator can be used to check shaft runout. If the shaft is bent or has flat spots, it should be replaced. (Chrysler)

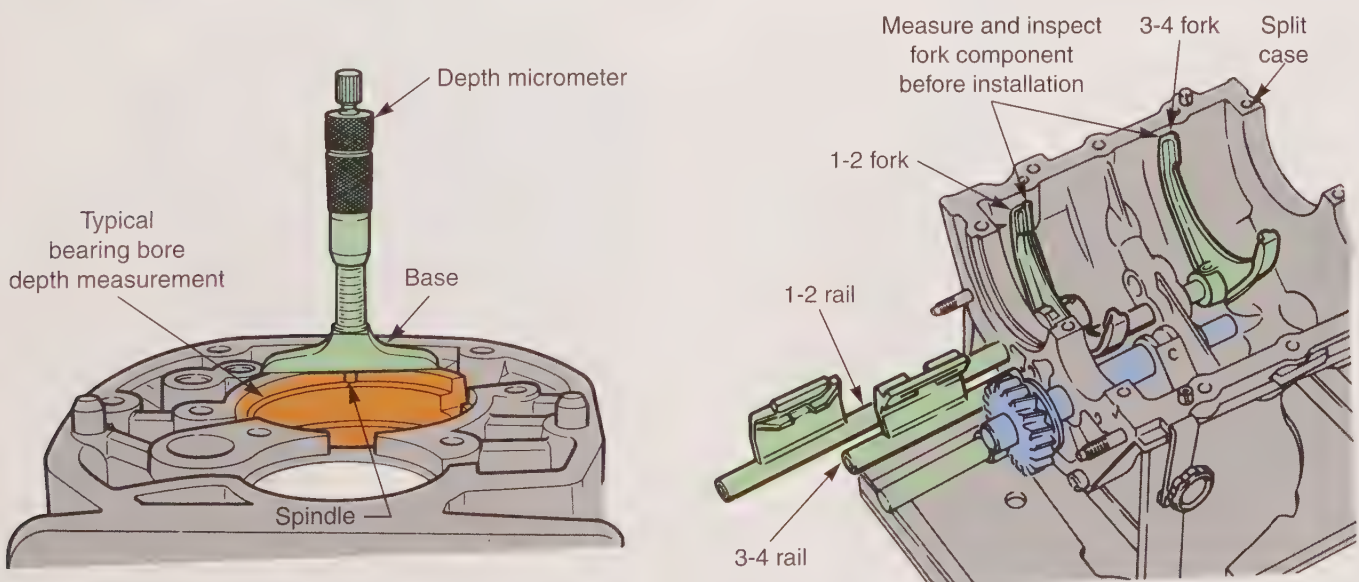


Figure 9-33. The mainshaft bearing bore depth is measured in this transmission case to ensure the bearing will not be too tight or too loose when the mainshaft is installed. Bore depth is adjusted with shims. (Ford)

Figure 9-34. To begin reassembly on this transmission, the shift forks and rails are installed. This is not the first step on every transmission. (Chrysler)

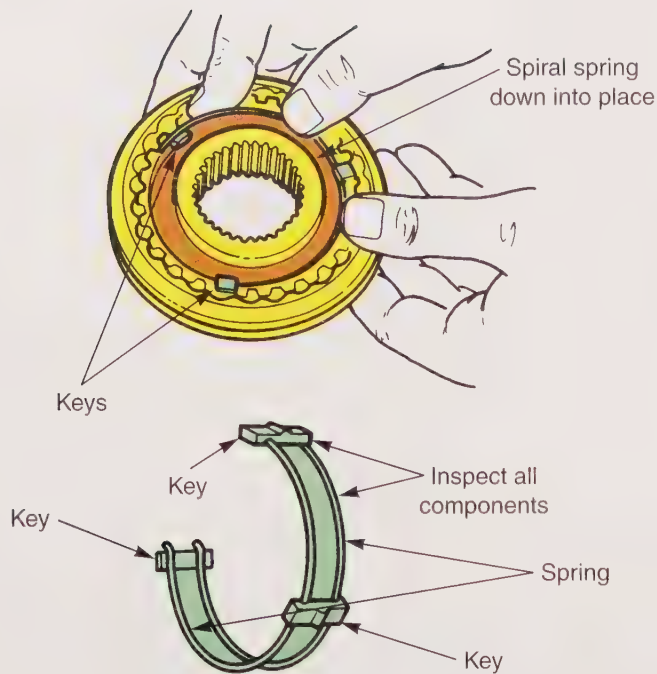


Figure 9-35. The synchronizers should be carefully assembled. The position of the inserts (keys) is critical. (Ford)

Installing Internal Components

Insert the cluster gear thrust washers on to each end of the transmission housing. Grease can be used to hold the washers in place.

Insert the countershaft gear through the rear opening of the transmission case and set it into position between the end thrust washers. Then, insert the countershaft through the case and push it through the countershaft gear. As the countershaft is pushed in, the dummy shaft will be pushed out.

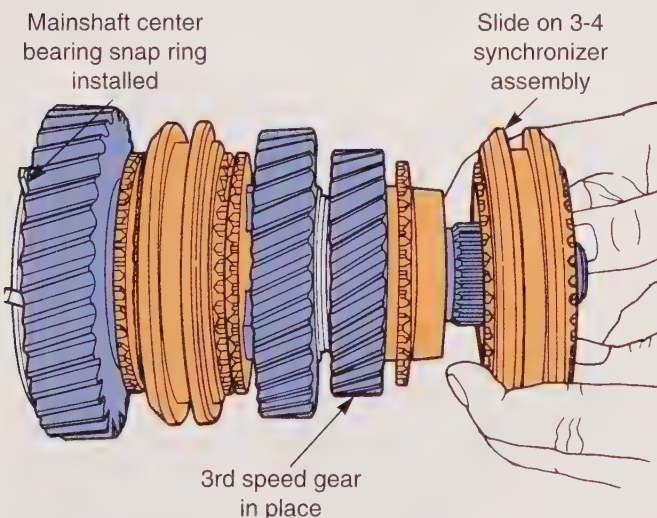


Figure 9-36. This shows the mainshaft gear assembly being put back together. Cleanliness and careful fitting are essential. Never force parts onto the shaft. Note that the number of gears will vary with each type of transmission. (Chrysler)

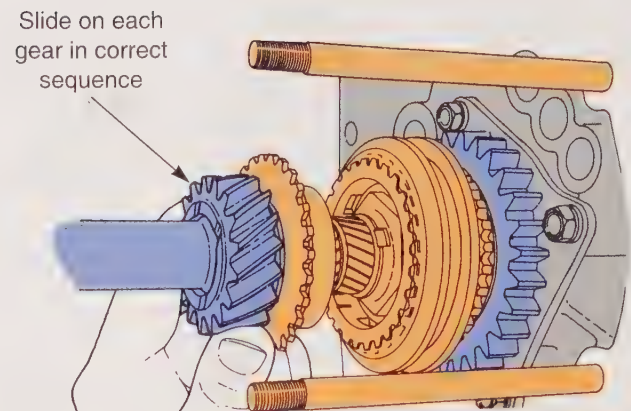


Figure 9-37. The mainshaft assembly shown here is not assembled until the mainshaft is installed in the transmission case. There are many variations to the assembly process, and the factory service manual should always be consulted. (Ford)

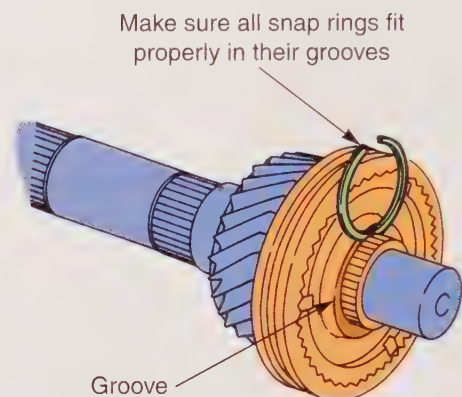


Figure 9-38. A simple check is shown for ensuring that a snap ring fits snugly in its groove. Some snap ring clearances are checked by inserting a feeler gauge of the proper thickness between the ring and groove. (Nissan)

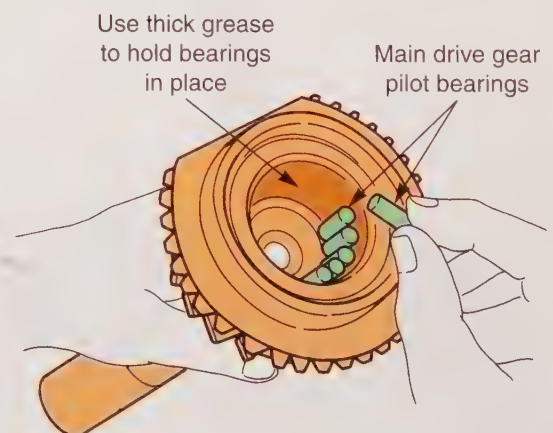


Figure 9-39. The needle bearings used between the main drive gear and the mainshaft are often loose, or uncaged, bearings. Use heavy grease to hold bearings in position while shafts are reinstalled.

If the countershaft uses a retainer pin or Woodruff key, set it in place before the shaft is completely installed, and push the shaft in until it bottoms out. If the shaft is held with snap rings, install them now. Be careful to install snap rings so they do not pop out.

Note that this procedure involving the countershaft gear assembly does not apply to all designs. Some countershaft gears do not rotate on a countershaft and needle bearings. Instead, the gear rotates on tapered roller bearings and there is no countershaft. The split-case transmission uses this type of setup. See **Figure 9-40**.

Once the countershaft gear is secured in position, countershaft gear endplay should be checked. The measurement is used to select the proper thrust washer or shim to bring endplay into specifications. Endplay is checked with a dial indicator, as shown in **Figure 9-41**. Install the indicator with the plunger touching the front end of the countershaft gear. Push the gear to the rear, and zero the dial indicator. (Make sure the plunger is still touching the countershaft gear.) Push the gear forward, and note the indicator reading. If the endplay is greater than specified, you must install thicker thrust washers or shims.

Once the countershaft gear is in place, the reverse idler gear can be installed if it is the type that fits into the case. Be sure to install the thrust washers.

With the countershaft gear and reverse idler gear assemblies in place, the mainshaft gear assembly and input shaft can be installed. Place the input shaft in the case. Install the front bearing, being careful not to dislodge the uncaged needle bearings. See **Figure 9-42**.

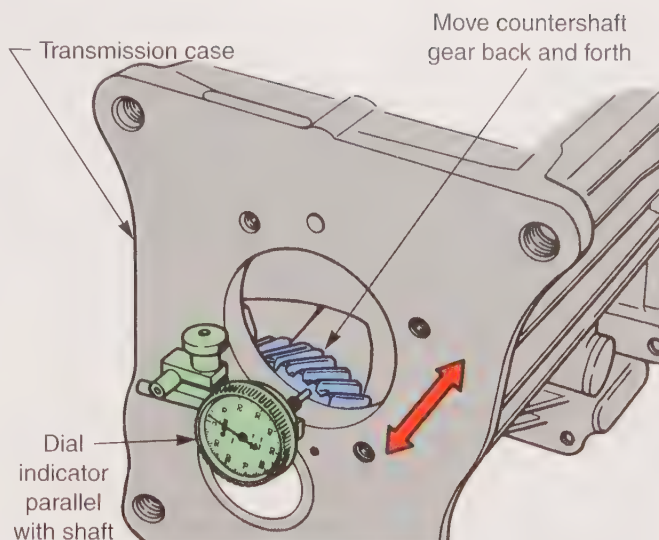


Figure 9-41. Dial indicators are often used to check endplay at various points in the reassembly process. Endplay checks are usually made with the transmission partly assembled. (Chrysler)

Install the mainshaft gear assembly through the rear of the transmission case. Carefully slide the nose of the mainshaft into the pilot bore behind the main drive gear, again, being careful not to dislodge the uncaged needle bearings. Once the mainshaft is in place, install the rear bearing, **Figure 9-43**. If the rear bearing is held in place by a snap ring, the snap ring should be installed now.

Once internal components are assembled, check their rotation and, once again, measure the gear endplay, or

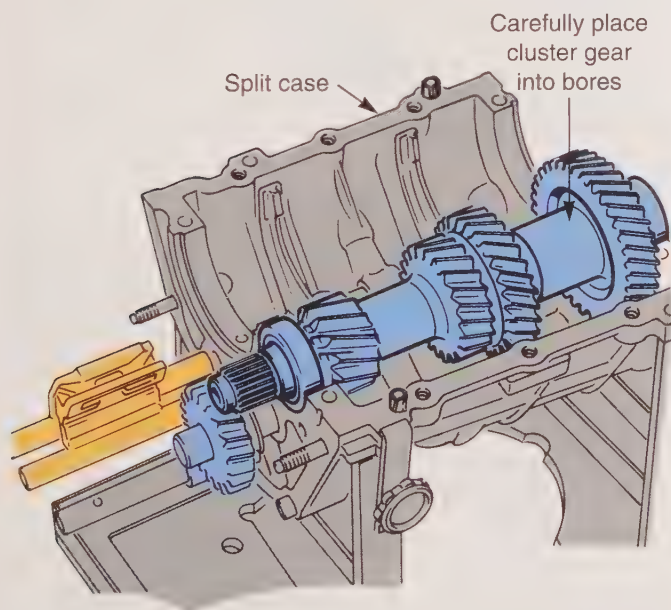


Figure 9-40. Countershaft gears in some designs, such as in this split-case transmission, use tapered roller bearings instead of thrust washers and needle bearings. This design does not employ a countershaft either. The countershaft gear is easily installed in this split-case transmission. Installation is more difficult in transmissions with one-piece cases. (Chrysler)

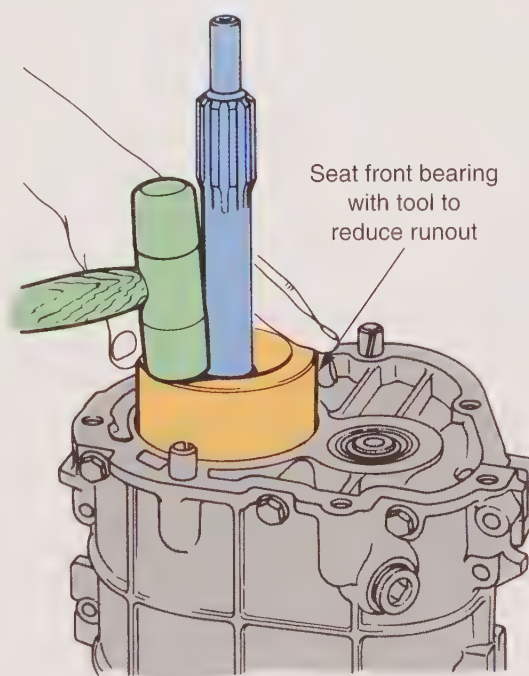


Figure 9-42. The front bearing for the input shaft may have to be pressed into place. Some front bearings may be loosely pressed into place and held by a snap ring. (Chrysler)

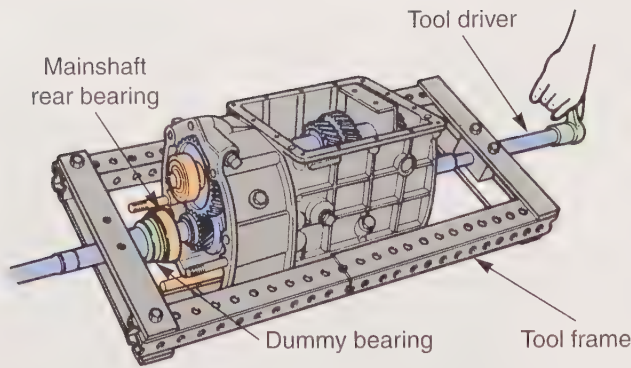


Figure 9-43. Rear bearings may also require pressing into place. This special tool makes the job easier. A dummy bearing, shown here, is used to expedite case assembly by aligning the shaft as it is put back together. This reduces the chance of damaging the real bearing. The dummy bearing is removed after the operation is finished. Some bearings are retained with snap rings. (Ford)

clearance. (Refer to **Figure 9-15.**) It must be checked to ensure that the gears do not bind when the transmission warms up during use. Proper clearance between the gears installed on a shaft is important to long transmission life. Clearance can be adjusted by changing the thickness of thrust washers or snap rings.

Installing External Components

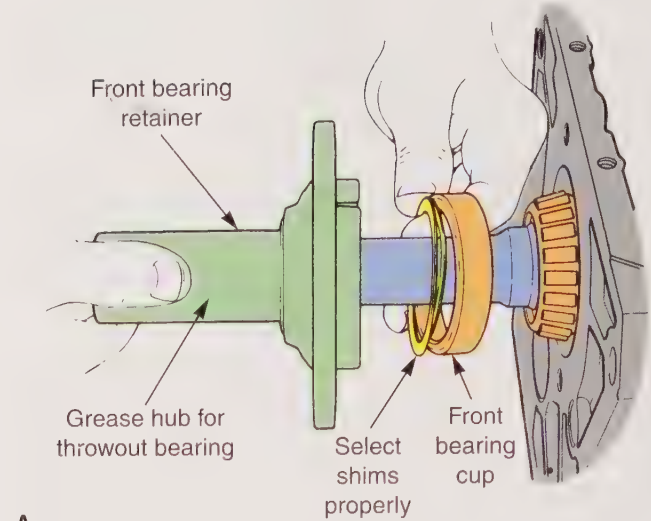
Install the extension housing gaskets. Always use new gaskets (and seals) when reassembling the transmission. If the reverse gear is in the extension housing, it should be installed now. Install the extension housing over the output shaft. Engage the reverse shift fork with the reverse gear, if necessary. Install and tighten the extension housing bolts.

Install the front bearing retainer, **Figure 9-44**, matching the alignment marks made earlier and torquing the fasteners to specifications. Then, check that the transmission input and output shafts turn with no binding. If the shafts do not turn freely, you must find out the reason and correct it.

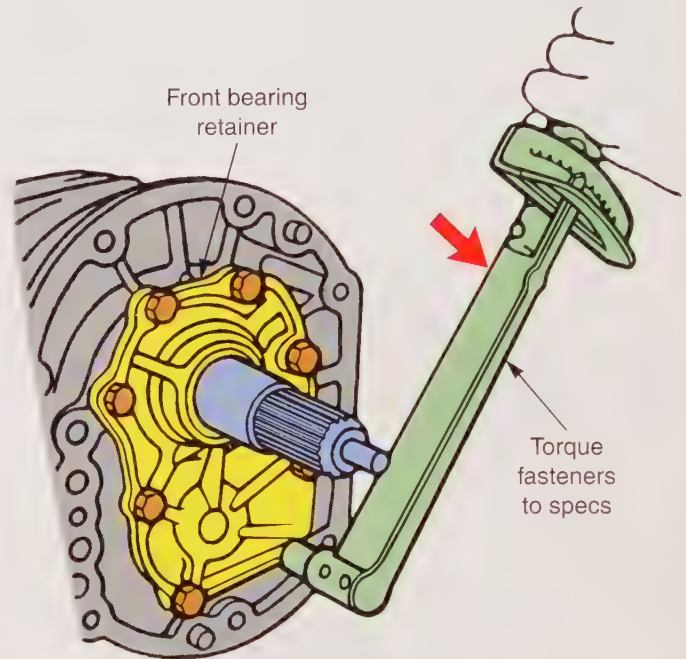


Caution: Never install a transmission that is broken internally or that is otherwise incorrectly assembled thinking that the parts will work themselves in and will operate smoothly. The transmission will be severely damaged within the first few minutes of operation!

The shaft endplay can be checked once the extension housing and front bearing retainer are tightened in place. This can be done with a dial indicator. Install the dial indicator at the front of the transmission, with the plunger in line with and touching the front end of the input shaft. Push the input shaft to the rear and zero the dial indicator. (Make sure the pointer is still touching the input shaft.) Then, push the output shaft forward and note the dial indicator reading. If the reading is not within specifications, replace the original thrust washers with thicker or thinner



A



B

Figure 9-44. The front bearing retainer should be carefully installed. A—When the front bearing is a tapered roller bearing, the front bearing cup is installed with a bearing retainer. Shims are added to obtain necessary preload. They eliminate endplay. The retainer hub should be lightly greased before transmission installation. B—The retainer bolts should be tightened with a torque wrench. (General Motors, Chrysler)

washers, as needed. Selective thickness thrust washers are available from dealer parts departments.

Replace the access covers, being sure to align the shift forks with the synchronizer sleeves where necessary. Use new gaskets at all locations. Be certain the transmission drain plug is in place. Reinstall the external case components removed as part of the transmission disassembly. Included among these components are the speedometer assembly and shift rail detent ball assemblies. Reinstall the internal gearshift lever assembly, if applicable. Once this is done, you can check internal shift linkage operation.

If the transmission case and bellhousing are an integral casting, lightly grease the throwout bearing and install it on the front bearing retainer hub. Connect the throwout bearing to the clutch fork and, if removed and if applicable, the clutch fork to the ball stud in the bellhousing.

Manual Transmission Installation

Transmission installation is the reverse of removal. As with removal, the vehicle should be on a hoist with the engine or bellhousing supported. If the procedures are performed properly, the transmission installation should go smoothly. See **Figure 9-45**. The following general procedures explain how to install a manual transmission in a vehicle. Note that you should always refer to the appropriate service information for specific procedures.

1. Check that the throwout bearing is in place on the clutch fork (or input shaft for integral-type casting). Place a small amount of grease on the pilot bearing. The throwout bearing surface should also be greased.
2. Raise the transmission with a transmission jack or floor jack, positioning it behind the engine. Carefully align the transmission with the engine. When the transmission is at the proper height and input/output shaft centerlines align with the crankshaft centerline, slide the input shaft into engagement with the throwout bearing, clutch disc hub, and pilot bearing. If the clutch has been disturbed, you may need to align the clutch disc. (Refer to Chapter 7.)

As the input shaft passes through the clutch disc hub and into engagement with the pilot bearing, the transmission case is brought to a tight fit with the bellhousing. On models with an integral-type case and housing, the bellhousing should snug up tightly to the engine. Alignment dowels should smoothly engage their matching holes.

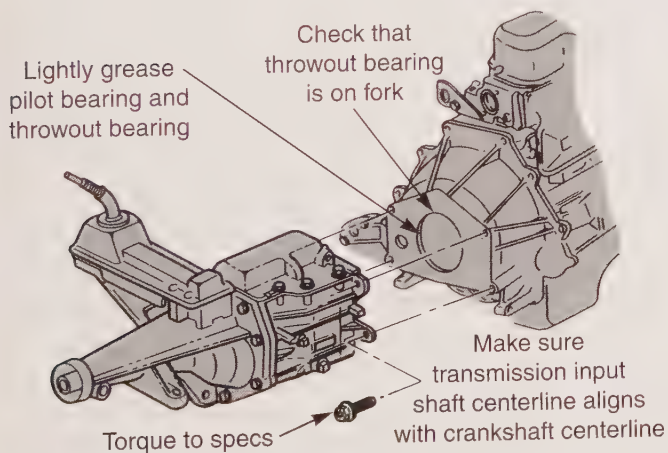


Figure 9-45. The transmission will install easily if the proper procedures are followed. The case of this transmission is separate from the bellhousing. General procedures are similar for this type and the one-piece integral casting. (General Motors)



Caution: Do *not* try to pull a binding transmission into position by tightening the bellhousing or transmission case attaching bolts. This will cause damage to the parts that are binding and can cause the bellhousing or transmission case ears to break. If parts are installed properly, the transmission should slide fully into place by hand.

3. Install the bellhousing or transmission case attaching bolts, as applicable. Ensure that the engine, bellhousing, and transmission are properly aligned after all the bolts are tight. There should be no gaps between any of the mating surfaces. As you tighten, check that no wires, brackets, or hoses are caught between mating surfaces.
4. Raise the transmission slightly with the jack until there is sufficient clearance to install the transmission crossmember. Place the crossmember under the transmission mount and install the attaching bolts. Then, install the attaching bolts that hold the crossmember to the vehicle frame.
5. If the external floor-shift gearshift lever assembly was removed, insert the gearshift lever through the hole in the floor pan. Bolt the shift mechanism to the extension housing. Install the external floor-shift linkage by reconnecting the shift rods to the shift levers at the transmission case.
6. Reconnect electrical connectors. Install parking brake hardware and exhaust pipes (if removed). Install the speedometer cable assembly. Reconnect the clutch linkage, including the return spring, at the clutch fork.
7. Install the drive shaft assembly, making sure to line up the marks you made during removal.
8. Fill the transmission to the proper level using specified lubricant. Install the fill plug and tighten.
9. If necessary, make preliminary linkage adjustments as specified earlier in this chapter. The clutch linkage may also need adjustment.
10. After all the drive train parts are reinstalled, lower the vehicle and reconnect any disconnected hardware under the hood, including the battery negative cable. Install the boot to the floor inside the passenger compartment. Screw the gearshift lever knob back on, if it was removed earlier.
11. After everything has been reconnected, push the clutch pedal a few times to see that the clutch engages and disengages properly. Also, move the gearshift lever to check operation of the shift linkage.
12. Carefully road test the vehicle, making sure the transmission (and clutch) operates properly. If any problems are detected, correct them before releasing the vehicle. Make any other adjustments as needed and recheck the transmission oil level.

Summary

To be successfully repaired, manual transmissions require careful diagnosis and the following of service procedures. Troubleshooting a transmission is as important as repairing it. The technician should always check out the easiest possible solutions before proceeding to the more complicated possibilities.

Like any mechanical part, the transmission will likely wear out in time. However, if properly operated and cared for, it should last for many thousands of miles. Many transmission problems are caused by careless operation or lack of service. Hard or fast shifting, lack of lubricant, or failure to make periodic linkage adjustments can cause early transmission failure.

Lubricant leaks are a common transmission problem. Leaks can usually be spotted by visual examination. The technician should make sure the leak is actually from the transmission before beginning repairs.

Hard shifting can be caused by external or internal transmission problems. Linkage or synchronizer problems can result in a gearshift lever that is hard to move. Slipping or jumping out of gear can also be caused by linkage problems. Worn internal parts can also cause this problem.

Transmission noises are usually heard as whining, rumbling, or roaring. Worn gears or bearings usually cause transmission noises. Often, the noise may come from another drive train component, such as the rear axle or drive shaft assemblies. Noise in Neutral may also come from the clutch assembly. Clunking noises are often caused by the drive shaft assembly universal joints.

Before removing a transmission, make sure that removal is needed. Many transmission problems can be corrected without removing the transmission. Linkage or other adjustments can almost always be made with the transmission installed.

The transmission can usually be removed without removing the engine. To begin removal, disconnect the battery and any other components under the hood, as required. The oil can be drained, and the linkage, drive shaft assembly, and crossmember should be removed. The transmission should be carefully lowered from the vehicle and taken to a workbench.

The transmission components are removed from the case in a step-by-step process. Usually the access covers are removed first, followed by the extension housing and the front bearing retainer. The mainshaft gear assembly can then be removed, followed by the input shaft, the countershaft gear assembly, and the reverse idler gear assembly. Carefully observe the position of all parts as they are disassembled. Mark similar parts as necessary. Once the transmission is disassembled, all parts should be thoroughly cleaned.

The transmission internal parts should be carefully checked for wear and damage. Checks can be made by observing parts for obvious damage and by checking for proper clearances with measuring instruments.

The transmission is reassembled in reverse order of disassembly. Check all parts for binding and other operating

problems as they are reinstalled in the case. Never attempt to reinstall a transmission with binding shafts. It will be badly damaged.

The transmission should be installed in the reverse order of removal. The input shaft should engage smoothly with the clutch disc splines. Do not attempt to force a sticking transmission into position by tightening the transmission case or bellhousing attaching bolts. The transmission lubricant should be placed in the transmission after the drive shaft assembly is installed. The shift and clutch linkage should be installed and adjusted. The components under the hood can be reconnected, and the vehicle can be road tested.

Review Questions—Chapter 9

Answer the following questions using the information provided in this chapter.

- The following items—seals, gaskets, plugs, too much oil in case, and damaged parts—are often the source of what transmission problem?
 - Gear jumpout.
 - Noisy transmission.
 - Gear clash.
 - Lubricant leakage.
- A manual transmission problem that occurs when gears and synchronizers do not quite fully engage is known as gear ____.
- What should you check when a manual transmission is only noisy in Neutral?
- Which of the following only includes items that can be serviced without removing the transmission?
 - External shift linkage, access covers, and speedometer assembly.
 - Mainshaft gears, internal shift linkage, and speedometer cable.
 - Front bearing retainer, damaged extension housing, and rear seal.
 - External shift linkage, drain plugs, and front bearing retainer seal.
- In your own words, explain a general procedure for removing a transmission from a vehicle.
- Once the ____ ____ has been removed, the transmission internals can be inspected for obvious damage.
- Name four measuring tools commonly used during a manual transmission rebuild.
- Why should you always refer to a service manual when rebuilding a manual transmission?
- Many transmission gears are held to their shafts with ____ _____. Stationary parts are usually attached with _____.
 - Welds.
 - Lock washers.
 - Locking pins.
 - Locking bolts.
- If the clutch was disturbed during transmission removal, the clutch disc may need to be ____.

ASE-Type Questions—Chapter 9

1. Technician A says that oil on the outside of the transmission case indicates a lubricant leak. Technician B says that leaks from other vehicle components are often mistaken for transmission leaks. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
2. Each of the following statements about manual transmissions is true *except*:
(A) many problems can be solved by linkage adjustments.
(B) oil level has no effect on manual transmission operation.
(C) some transmission problems can be diagnosed during a test-drive.
(D) water in the oil can cause gear pitting.
3. Each of the following is a cause of a no-drive condition on a manual transmission *except*:
(A) water in the transmission.
(B) stripped gear(s).
(C) broken transmission shaft.
(D) transmission locked in two gears.
4. A manual transmission shifts hard in all gears. Technician A says that a worn or misadjusted shift linkage could be the cause. Technician B says that a worn or misadjusted clutch linkage could be the cause. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
5. Gear clash in only one gear is usually caused by _____.
(A) clutch misadjustment
(B) a worn synchronizer
(C) a faulty clutch
(D) low lubricant level
6. Technician A says that external shift mechanisms should be lubricated with water-resistant grease. Technician B says that internal shift linkage is lubricated by the transmission lubricant. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
7. During transmission removal, which of the following could allow the engine to fall backwards when the transmission crossmember is removed?
(A) Broken engine mounts.
(B) Loose transmission case-to-bellhousing bolts.
(C) Loose bellhousing-to-engine bolts.
(D) Broken transmission mount.
8. Technician A says that some transmission cases and bell housings are one-piece units. Technician B says that transmission cases are often attached to the bellhousing by four bolts. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
9. Technician A says that all manual transmissions are internally constructed in the same way. Technician B says that manual transmission external parts should be removed before the internal parts are removed. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
10. Technician A says that a visual inspection is all that is necessary to fully examine manual transmission internal parts. Technician B says that a parts inspection requires that some internal parts be measured using micrometers or feeler gauges. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
11. Transmission endplay can be adjusted by using special _____.
(A) thickness shims
(B) length bolts
(C) thickness gaskets
(D) seal rings
12. Technician A says that a transmission that is binding internally should be installed and allowed to run in. Technician B says that a transmission that gets hung up while being installed should be pulled into place by tightening the attaching bolts. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.

13. Which of the following must be installed *first* during transmission reinstallation?
- (A) Throwout bearing.
 - (B) Driveshaft.
 - (C) Rear transmission mount.
 - (D) Speedometer cable when used.
14. A transmission makes a grinding noise when shifted into Third. Technician A says that a synchronizer may be bad. Technician B says that the countershaft gear may have chipped teeth. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
15. A transmission makes excessive noise, but only in Second. Technician A says to check the lubricant level. Technician B says to check for problems with bearings of the countershaft gear assembly. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.



Chapter 10

Manual Transaxle Construction and Operation

After studying this chapter, you will be able to:

- ☐ Identify the major parts of a manual transaxle.
- ☐ Describe the construction of a typical manual transaxle.
- ☐ Explain the operation of a typical manual transaxle.
- ☐ Trace the power flow through manual transaxles used with transverse and longitudinal engines.
- ☐ Compare manual transaxle design variations.

Technical Terms

Manual transaxle shafts

Manual transaxle differential
assembly

Manual transaxle case

Manual transaxle input shaft

Manual transaxle output shaft

Introduction

Although rear-wheel drive vehicles are still used today, front-wheel drive vehicles with transaxles are far more common. The drive train of the front-wheel drive vehicle is much lighter than that of the rear-wheel drive vehicle, since it eliminates the drive shaft assembly and rear axle housing. Placing all the drive train parts in the front of the vehicle also allows the manufacturer to eliminate the transmission hump found on the floor of rear-wheel drive vehicles. This increases passenger room.

Manual transaxle operating principles are similar to those of a manual transmission and differential assembly. The major difference in a transaxle is that all parts are usually together in one housing. The manual transaxle has the same kinds of gears, synchronizers, and shift linkage as a manual transmission. It contains the same type of differential case assembly, performing the same job as that found on a rear axle assembly. The greatest differences occur in the shape of the transaxle case and the placement of the parts within the case. An obvious external difference is the two CV axles connected to the transaxle, as opposed to the drive shaft assembly that connects to the rear-wheel drive manual transmission.

This chapter will familiarize you with the parts and operating principles of manual transaxles. Many parts resemble those used on a rear-wheel drive vehicle, although

they are arranged differently. This chapter indicates which parts are different from those of a rear-wheel drive vehicle. It explains how power flows through the two major types of transaxles, as well as the differences in parts and layout between the two types. Transaxles used on modern rear-wheel drive vehicles are also briefly described.

Purpose of the Manual Transaxle

A manual transaxle (or automatic transaxle) is a drive unit that combines a transmission and a differential assembly in one case. See **Figure 10-1** and **Figure 10-2**. Although transaxles can be used on rear-engine, rear-wheel drive vehicles, most transaxles are found on vehicles with front-wheel drive. The transaxle is attached to the rear (output end) of the engine. The transaxle and engine assembly is attached to the vehicle's frame and body through flexible engine mounts. The flexible mounts reduce vibration transfer from the engine and transaxle to the passenger compartment.

The basic job of the transaxle is to transfer power from the engine to the drive axles. The transaxle must also be able to provide the proper gear ratio for varying operating conditions and allow the drive wheels to make turns. Power is received from the engine through a clutch assembly.

The transmission portion of the transaxle is used to select the proper gear ratio for any driving situation and to

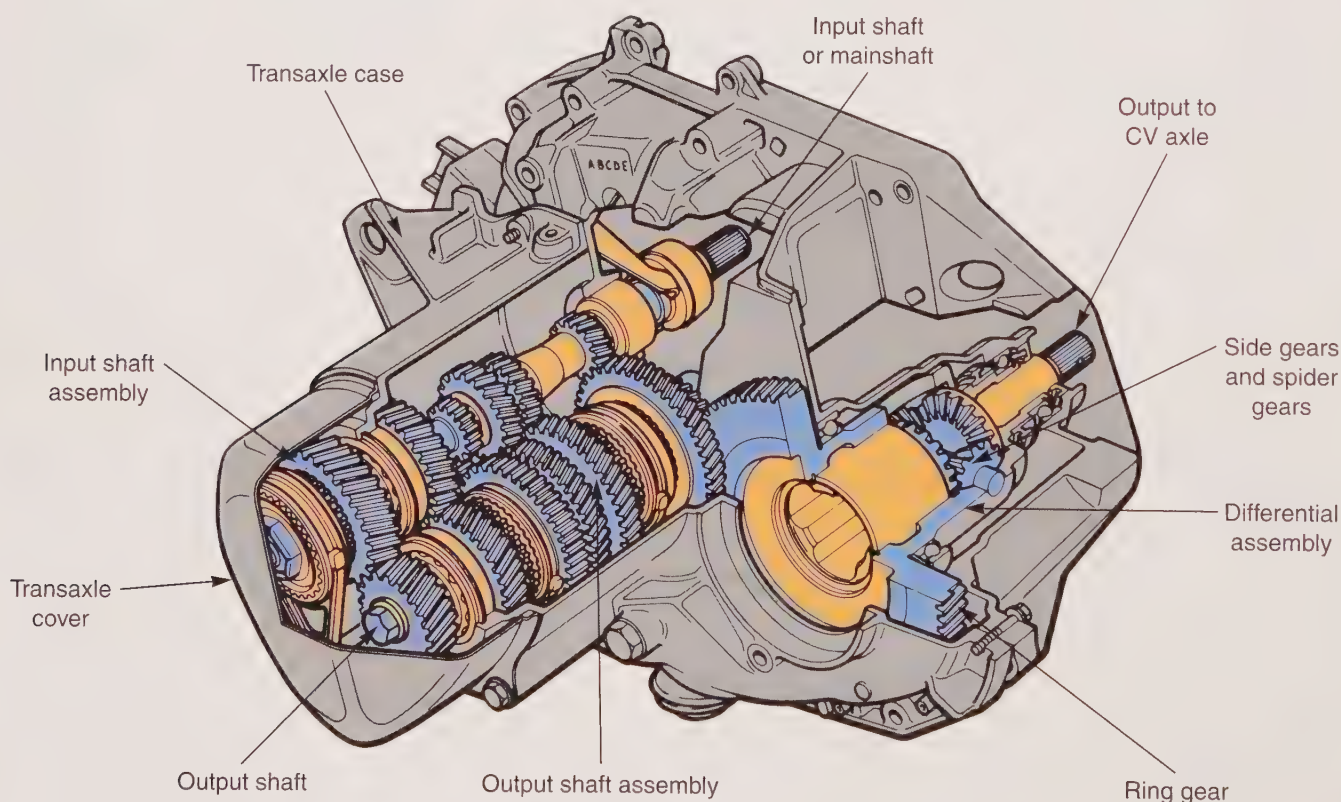
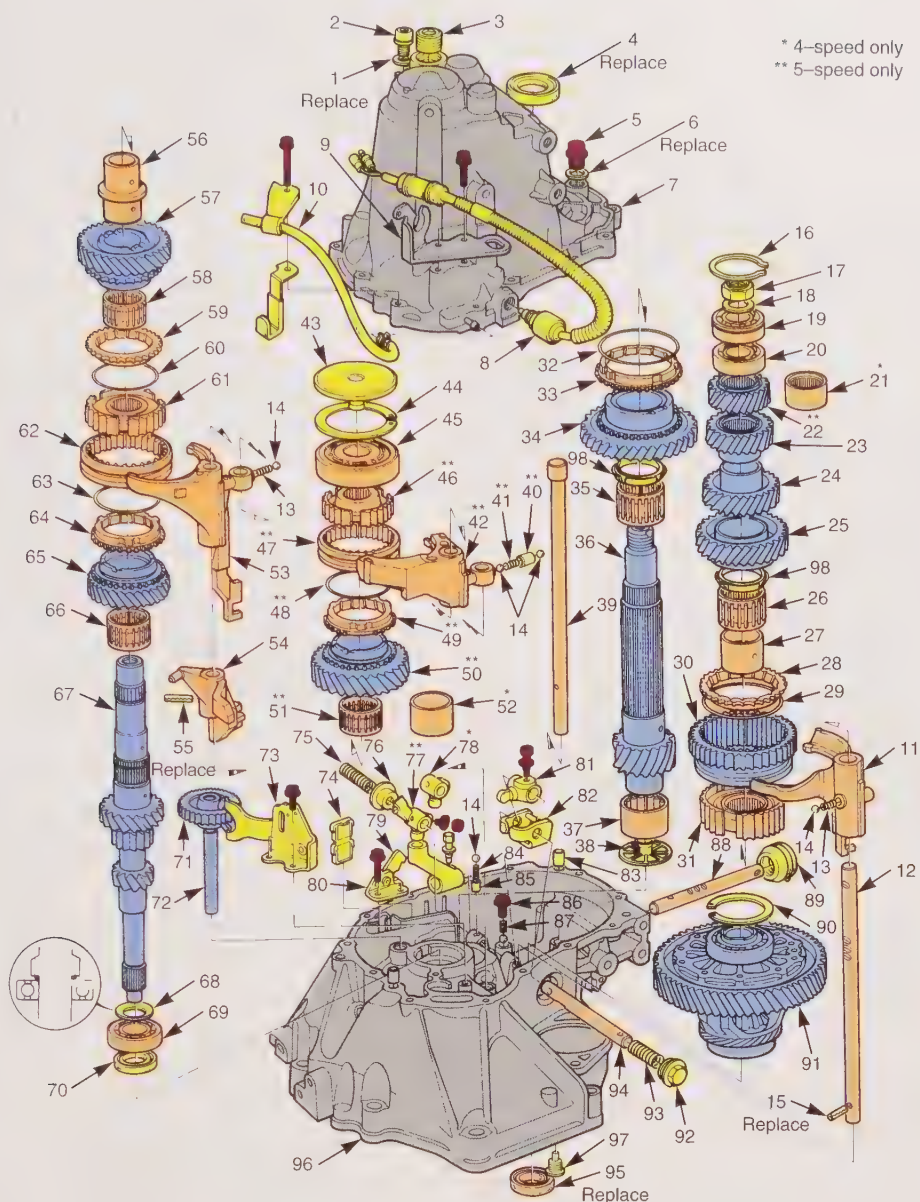


Figure 10-1. This cutaway shows the major transaxle parts, including the case and covers, input and output shafts and gears, and differential assembly. All transaxles, while varying in details, have these basic parts. Note that this particular transaxle is used with a transverse engine. (Chrysler)



- | | | | |
|------------------------------|--------------------------------------|-----------------------------------|--------------------------------|
| 1. Washer | 26. Needle bearing | 51. Needle bearing (5-speed only) | 75. Reverse select spring |
| 2. Oil drain plug | 27. Spacer collar | 52. Collar (4-speed only) | 76. Reverse return select |
| 3. 32 mm sealing bolt | 28. Synchro ring | 53. 3rd/4th shift fork | 77. Shift arm C (5-speed only) |
| 4. Oil seal | 29. Synchro spring | 54. Shift piece | 78. Shift arm C (4-speed only) |
| 5. Oil filler bolt | 30. Reverse gear | 55. Spring pin | 79. Shift arm A |
| 6. Sealing washer | 31. Synchro hub | 56. Spacer collar | 80. Reverse lock cam |
| 7. Transmission housing | 32. Synchro spring | 57. 4th gear | 81. Shift arm B |
| 8. Back-up light switch | 33. Synchro ring | 58. Needle bearing | 82. Interlock |
| 9. Clutch cable bracket | 34. Countershaft 1st gear | 59. Synchro ring | 83. Dowel pin |
| 10. Breather tube | 35. Needle bearing | 60. Synchro spring | 84. Spring |
| 11. 1st/2nd shift fork | 36. Countershaft | 61. Synchro hub | 85. Spring collar |
| 12. 1st/2nd shift fork shaft | 37. Needle bearing | 62. Synchro sleeve | 86. Spring bolt |
| 13. Shift fork spring | 38. Oil barrier | 63. Synchro spring | 87. Spring |
| 14. Steel ball | 39. 5th reverse shift fork shaft | 64. Synchro ring | 88. Shift rod |
| 15. Spring pin | 40. Roller (5-speed only) | 65. 3rd gear | 89. Boot |
| 16. Snap ring | 41. 5th detent spring (5-speed only) | 66. Needle bearing | 90. Shim |
| 17. Countershaft locknut | 42. 5th shift fork (5-speed only) | 67. Mainshaft | 91. Differential assembly |
| 18. Washer | 43. Oil guide plate | 68. Spring washer | 92. 28 mm plug |
| 19. Ball bearing | 44. Thrust shim | 69. Ball bearing | 93. 1st/2nd select spring |
| 20. Needle bearing | 45. Ball bearing | 70. Oil seal | 94. Shift arm shaft |
| 21. Collar (4-speed only) | 46. Synchro hub (5-speed only) | 71. Reverse idler gear | 95. Oil seal |
| 22. Countershaft 5th gear | 47. Synchro sleeve (5-speed only) | 72. Reverse idler shaft | 96. Clutch housing |
| 23. Countershaft 4th gear | 48. Synchro spring (5-speed only) | 73. Reverse shift holder | 97. Interlock guide bolt |
| 24. Countershaft 3rd gear | 49. Synchro ring (5-speed only) | 74. Magnet | 98. Friction damper |
| 25. Countershaft 2nd gear | 50. 5th gear (5-speed only) | | |

Figure 10-2. Exploded view of a transaxle used with a transverse engine shows the internal parts in detail. (Honda)

move the vehicle in reverse. The differential portion of the transaxle allows the vehicle to make turns while power is being delivered. The differential assembly drives two CV axles that turn the front drive wheels.

Operating the Manual Transaxle

From the driver's point of view, operation of the manual transaxle is identical to that of the rear-wheel drive manual transmission. The driver selects gears through a gearshift lever and manual clutch, pushes the clutch pedal to disengage the clutch, and moves the gearshift lever to the desired gear position. Moving the gearshift lever operates the linkage that engages gears inside the transmission. The driver then releases the clutch pedal to engage the clutch. With the clutch engaged, the gears transfer power through the transaxle to the output shaft. The vehicle can then move in the selected gear position.

Construction and Internal Operation

There are two basic kinds of transaxle construction. The type used depends on engine placement in the vehicle. Engine installation can be transverse (crosswise) or longitudinal (lengthwise), **Figure 10-3**. Major manual transaxle components include the following:

- ❑ **Manual transaxle shafts**—support gears and directly or indirectly transfer rotation from the clutch disc to the transaxle differential assembly.
- ❑ **Transaxle transmission gears**—transmit power and provide a means of changing vehicle torque, speed, and direction.

- ❑ **Synchronizers**—bring certain transmission gears to the same rotational speed as their associated shaft before sliding in mesh with the gears and locking them to the shaft. Synchronizers are used to prevent gear clash. They operate in the same way as synchronizers on rear-wheel drive manual transmissions.
- ❑ **Shift forks**—pronged units for moving transmission gears or synchronizers on their shaft for gear engagement.
- ❑ **Manual transaxle shift linkage**—connects the gearshift lever to the shift forks. Linkage consists of shift levers and rods or cables.
- ❑ **Manual transaxle differential assembly**—receives power from the transaxle transmission. The differential assembly contains differential drive gears, spider gears, and side gears. It allows the vehicle to make turns, allowing each drive wheel to rotate at a different speed. Construction and operation is very similar to that of a rear-wheel drive differential.
- ❑ **Manual transaxle case**—encloses transaxle shafts, gears, synchronizers, shift forks and linkage, and lubricating oil. It also encloses the differential assembly.

Manual Transaxle Shafts

Manual transaxles contain several shafts, including input, output, and reverse idler shafts. These shafts are made of hardened steel. They must fit in the case with very close tolerances. In some designs, the shafts rotate on ball bearings, straight roller bearings, or needle bearings. Thrust washers placed between gears on these shafts and the transaxle case control endplay. In other designs, shafts rotate on tapered roller bearings to control endplay. Manual transaxle shafts are arranged differently in different transaxles, but their basic function is the same.

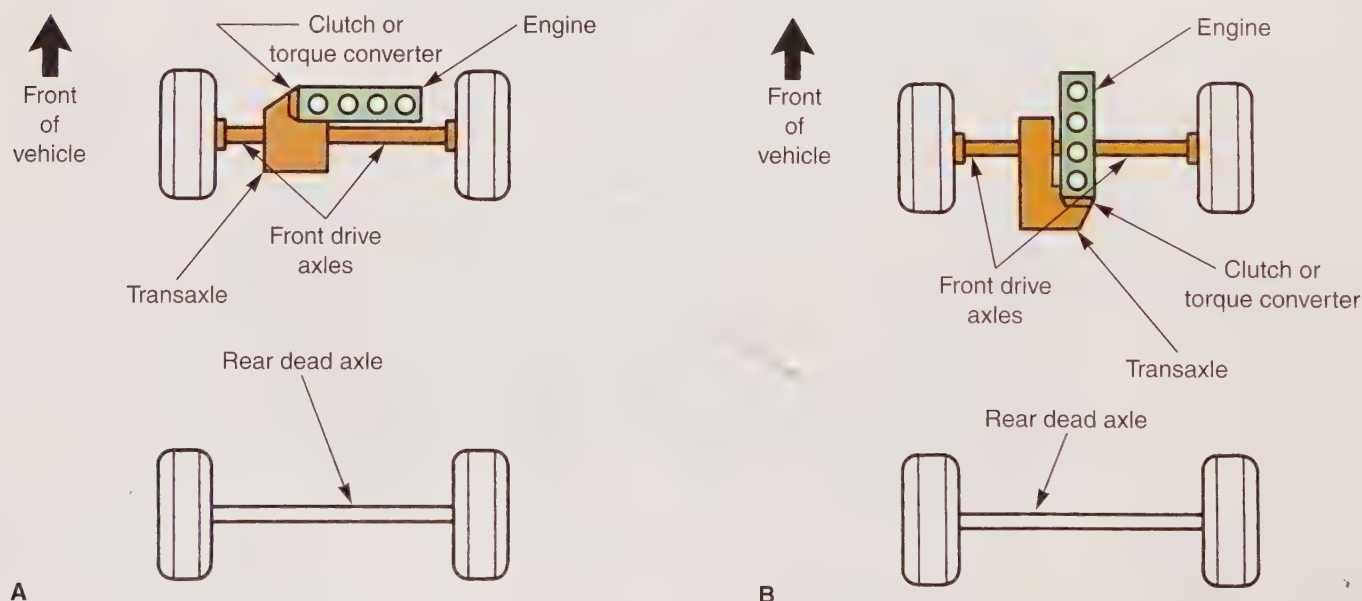


Figure 10-3. A—Front-wheel drive vehicle with a transverse-mounted engine. B—Front-wheel drive vehicle with a longitudinally mounted engine.

Manual transaxle input shaft

The **manual transaxle input shaft** receives power from the engine through the clutch. On transaxles used with transverse engines, the input shaft is a single shaft that is splined to the clutch friction disc. It extends from the clutch disc into the transaxle transmission, **Figure 10-4**. On transaxles used with longitudinal engines, the input shaft may be connected to the clutch through an additional shaft and a drive chain or drive gears. This is shown in **Figure 10-5**. The engine turns the input shaft whenever the clutch is engaged.

The transaxle input shaft holds gears and synchronizers, which are mounted on the shaft in the same manner as on a rear-wheel drive manual transmission. Excessive shaft movement is prevented by front and rear bearings and by thrust washers. The input shaft is sometimes referred to as the mainshaft or the input cluster gear.

Manual transaxle output shaft

The **manual transaxle output shaft** contains gears that mate with the input shaft. This rotating shaft, which holds output gears and synchronizers, delivers power to the transaxle differential. The output shaft is sometimes referred to as the mainshaft, the countershaft, or the pinion shaft.

Note that some transaxle designs have an output shaft and a separate countershaft. This arrangement is usually seen in transaxles used with longitudinal engines. Such

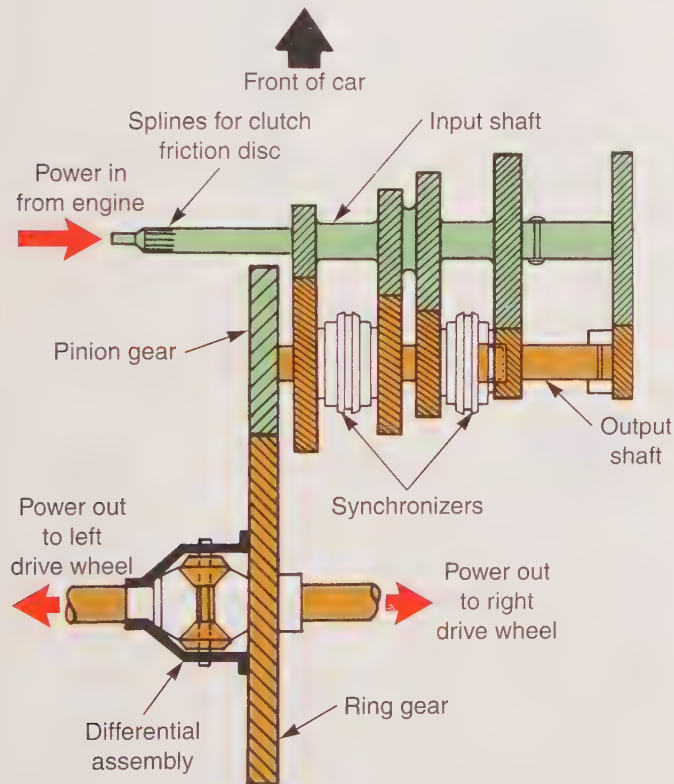


Figure 10-4. With the transverse engine, the crankshaft and input shaft centerlines are in alignment. Also, the crankshaft and drive axles are oriented in the same direction so diverting power flow by 90° in the differential is not necessary.

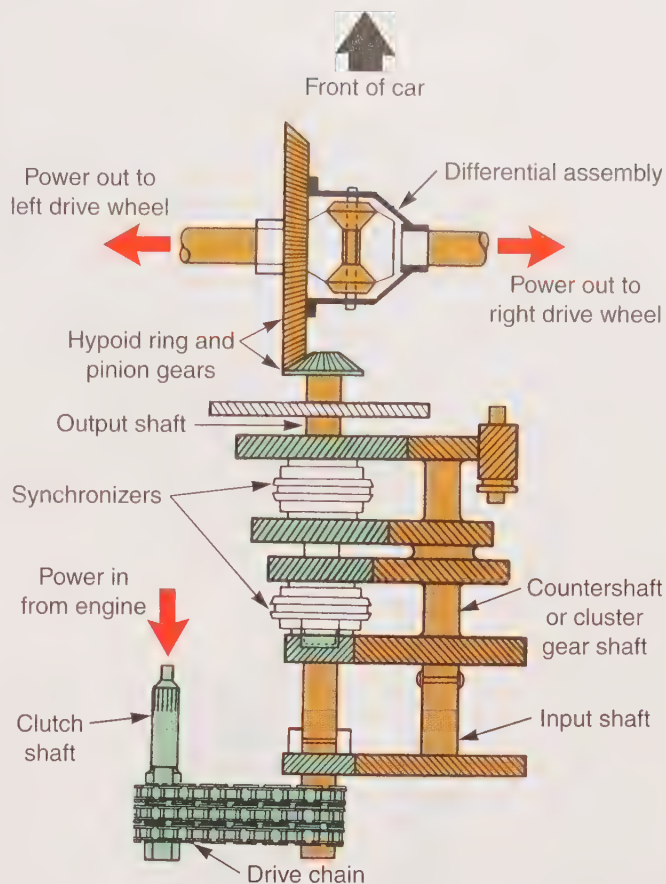


Figure 10-5. With the longitudinal engine, the crankshaft and input shaft have different centerlines. The drive chain transfers power from the clutch. A hypoid ring and pinion diverts power flow at the differential assembly.

output shafts use a hypoid drive pinion gear to engage the ring gear in the differential portion of the transaxle.

Reverse idler shaft

Some transaxles have a reverse idler shaft. This is a short shaft that supports the reverse idler gear, which is an additional gear used to reverse output shaft direction so the vehicle can back up. The reverse idler shaft is normally stationary and mounts in the case.

Manual Transaxle Transmission Gears

The gears of the transmission portion of the manual transaxle are similar to the gears of a rear-wheel drive manual transmission. Spur gears or, more often, helical gears are mounted on the transaxle transmission shafts. Some gears are cut directly onto the shaft, while others are splined to the transmission shaft. Some gears rotate on the shaft, riding on a bushing or on needle bearings placed between the gear and the shaft.

The gears of the transaxle transmission are used to transmit power and to provide different gear ratios, as well as reverse. Transaxle gears, like rear-wheel drive transmission gears, are made of machined high-strength steel.

The gears are heat-treated for extra strength. **Figure 10-6** shows typical manual transaxle transmission gears.

Some gears are in constant mesh, while others are not. Which gears are permanently in mesh varies with the transaxle manufacturer. The number of gears on the input and output shafts also varies according to the manufacturer's design.

The size of the gear is an indication of the ratio of the gearset: the smaller the gear on the input shaft and the larger the gear on the output shaft, the greater the reduction. On the input shaft, for instance, the gear for low is smaller than the gear for second. This can be seen in **Figure 10-7** and **Figure 10-8**.

Manual transaxle gears are usually lubricated by gear oil. A few transaxles use automatic transmission fluid as the lubricant. The rotation of the gears distributes the oil to the moving parts of the transaxle. In addition, oil passages in the shafts permit lubrication of gear bushings and needle bearings **Figure 10-9**.

A few transaxles are equipped with special washers that pump oil to the gears and bearings. These washers are made of spring steel. As the driver shifts gears, the direction of the thrust loading on the input and output shafts changes, causing the washers to flex. As they flex, the washers create a pumping action that distributes oil to critical areas of the transaxle.

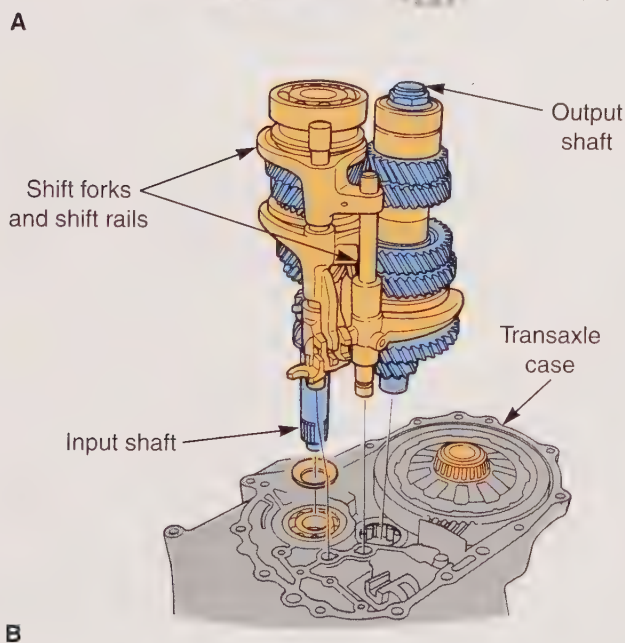
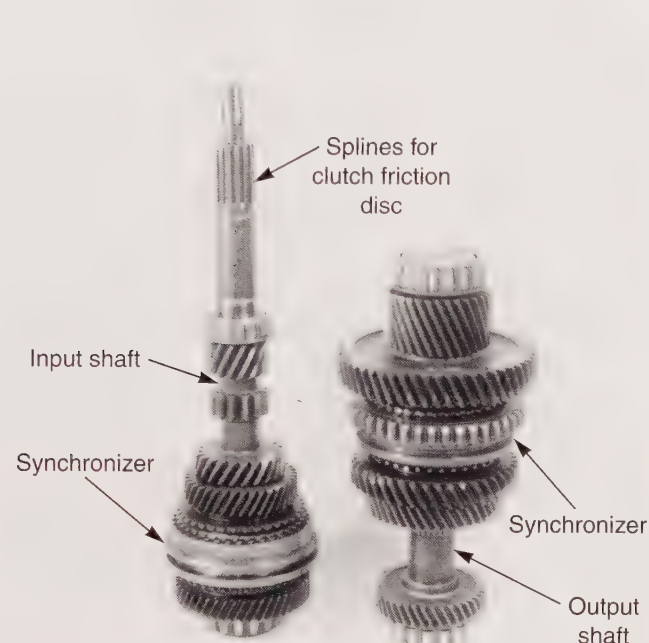


Figure 10-6. A—Transaxle transmission gears, bearings, and synchronizers on input and output shafts. B—Shift rails and shift forks on input and output shaft assemblies. (General Motors, Honda)

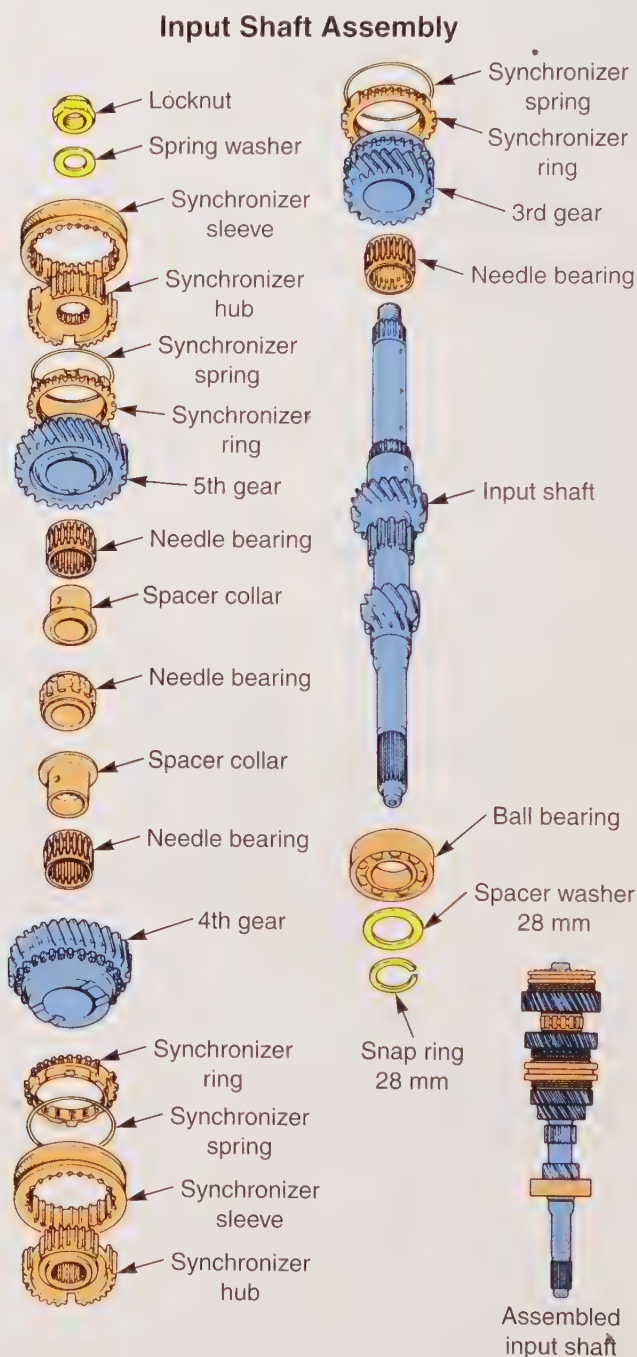


Figure 10-7. Exploded view of a manual transaxle input shaft. (Honda)

Output Shaft Assembly

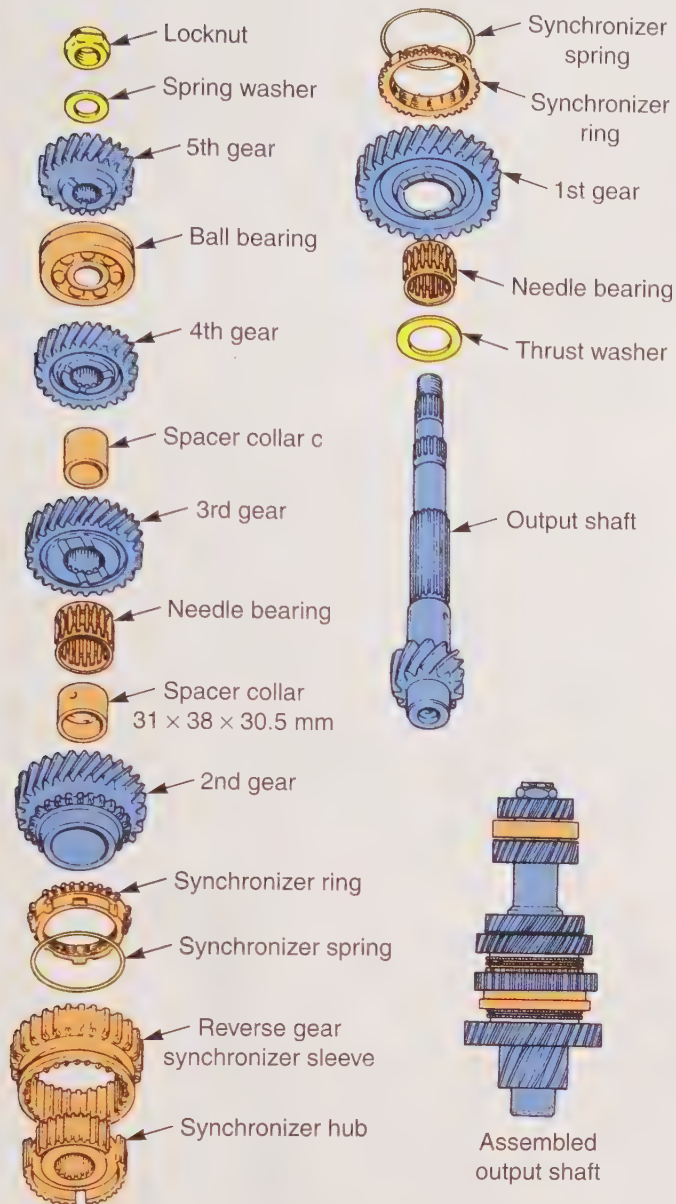


Figure 10-8. Exploded view of a transaxle output shaft. (Honda)

Synchronizers

Before freewheeling gears can be locked to the turning shaft on which they ride, they must be turning at almost the same speed as the shaft. This is done in the transaxle transmission with gear synchronizers, **Figure 10-10**. The synchronizers are placed along the shaft between these gears, and they are splined to the shaft. They match the speed of mating gears to their own speed (output shaft speed) in the process of locking a gear to its shaft. If the gear speeds were not synchronized in this way, the gears would grind against each other before meshing, causing gear clash. As a result, shifting would be difficult and noisy, and the gears could be damaged.

Manual transaxle transmissions are synchronized in all forward gears. Reverse gear is unsynchronized.

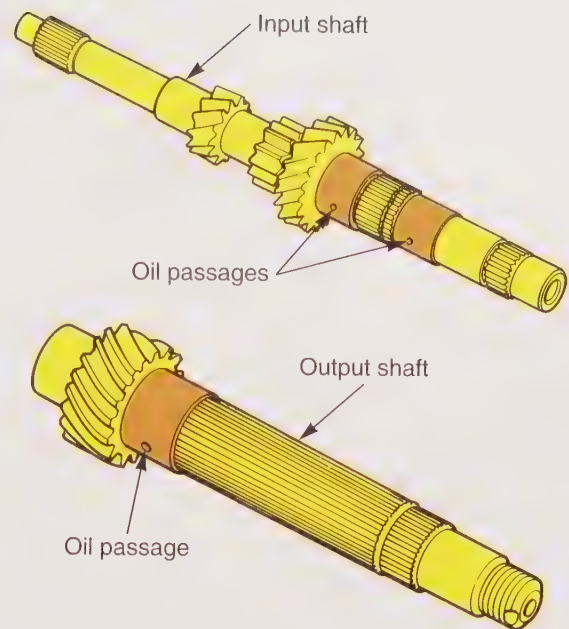


Figure 10-9. In these input and output shafts, oil passages are used for lubricating bearings. (Honda)

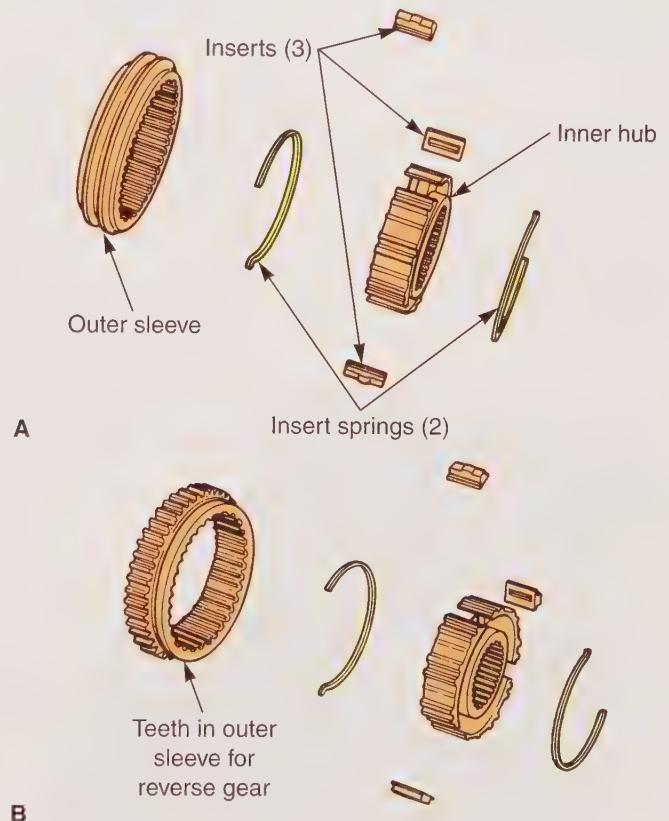


Figure 10-10. Synchronizers (shown here) act as clutches, bringing mating gears to the same speed before they are fully engaged. Blocking rings, considered part of the synchronizer assembly, are not shown here. A—The synchronizer is similar to that found in rear-wheel drive manual transmission. B—The gear cut into the outer sleeve of this synchronizer serves as reverse gear. (Chrysler)

Construction and operation of transaxle synchronizers is essentially the same as that of the manual transmission. (Refer to Chapter 8 for a detailed discussion of synchronizers.) One difference between the synchronizers of transaxles and those of manual transmissions is that transaxle synchronizers may be located on both input and output shafts. In the manual transmission, they are found only on the output shaft.

Shift Forks

Shift forks, like the one shown in **Figure 10-11**, are made to slip into a groove cut into the outer sleeve of a synchronizer assembly. They are usually made from steel or cast iron. Some shift forks have nylon inserts at the point where they contact the outer sleeve to reduce wear and noise.

Shift fork action in a manual transmission is identical to that of shift forks in a rear-wheel drive manual transmission. The shift fork moves in a straight line to push the synchronizer outer sleeve and blocking ring into engagement with the mating gear. The design permits the synchronizer assembly to continue to rotate as the outer sleeve is moved. The shift fork, in conjunction with the synchronizer, selects one gear when it is pushed forward and selects another gear when it is pushed backward. The shift forks are operated by the manual transaxle shift linkage.

Manual Transaxle Shift Linkage

The transaxle shift forks are operated by the vehicle driver through a series of shafts, levers, links, and, sometimes, cables. There are many ways to transfer the force applied to the gearshift lever to the transaxle transmission gears. Most transaxle shift linkages are very simple, both in

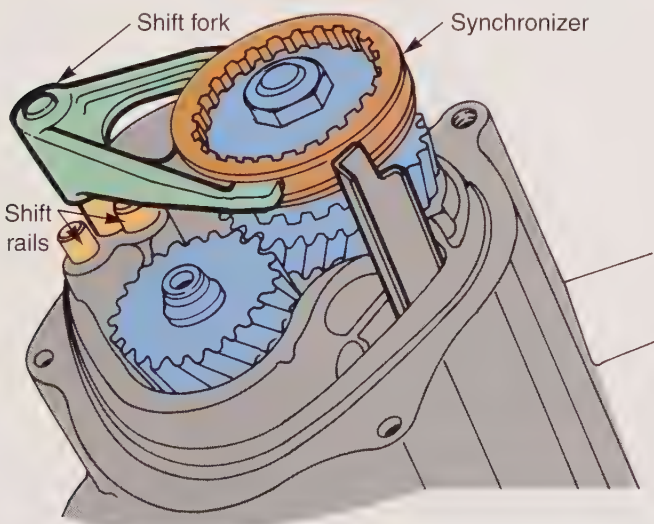


Figure 10-11. A shift fork, such as the one shown here, fits into the synchronizer outer sleeve. The fork can slide the sleeve forward or backward as the sleeve rotates with the shaft. (Chrysler)

construction and in operation. The gearshift lever and the components that make up a manual transaxle shift linkage are discussed in this section.

Gearshift lever

A typical gearshift lever is shown in **Figure 10-12**. The gearshift lever may have a knob with a button, which is depressed to obtain reverse. The lever may alternately have a sliding ring, which is moved upward to obtain reverse. Either mechanism prevents shifting into reverse while moving forward. Note that the lever extends downward through a hole in the vehicle floor pan to the external shift linkage. This hole is sealed by a flexible rubber boot. Sometimes, two boots are used.

External shift linkage

The gearshift lever operates a shift mechanism under the dust boot. Since the transaxle is placed far ahead of the passenger compartment, external linkage must be used to connect the shift mechanism and transmission internals.

External shift linkage consists of a series of levers and rods or cables that connect the gearshift lever with the transaxle internal shift linkage. A typical rod-and-lever linkage system is shown in **Figure 10-13**. A typical cable linkage system is shown in **Figure 10-14**. The cable linkage system shown has two selector cables. Other systems may

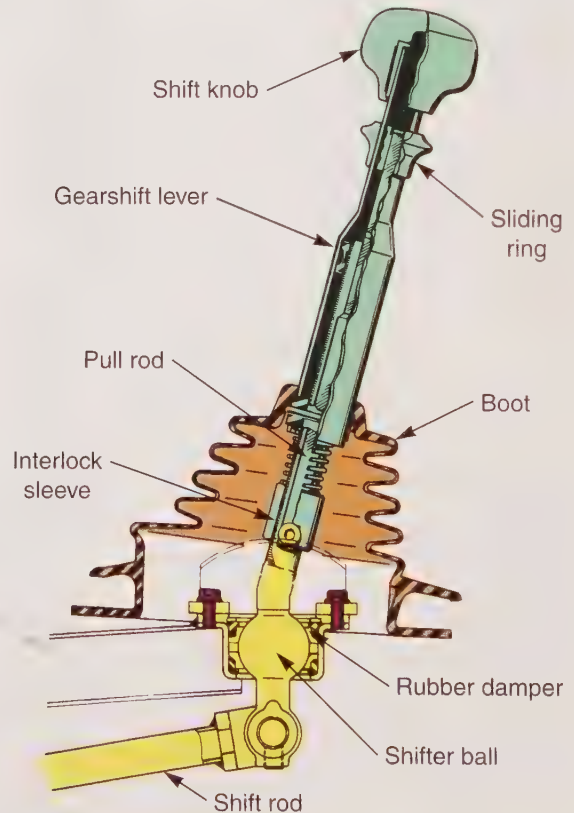


Figure 10-12. A typical gearshift lever. The boot keeps dirt and water out of the passenger compartment. The sliding ring is pulled up to move the lever to the reverse position, but not all gearshift levers have such a feature. (Volvo)

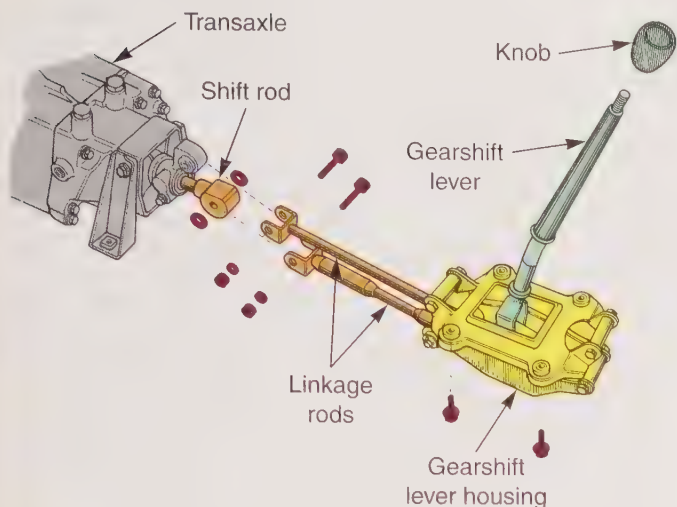


Figure 10-13. This is a rod-and-lever type of shift linkage. The rods and levers connect the gearshift lever with the transaxle internal shift linkage. (Toyota)

use only one cable, or as many as three. The shift linkage system shown in **Figure 10-15** uses only a single rod to connect the gearshift lever assembly to shift levers and rods at the transaxle. A few linkage systems use a combination of rods and cables to change gears.

Rod-and-lever linkage parts are attached with cotter pins through drilled holes in the shift rods, in the same

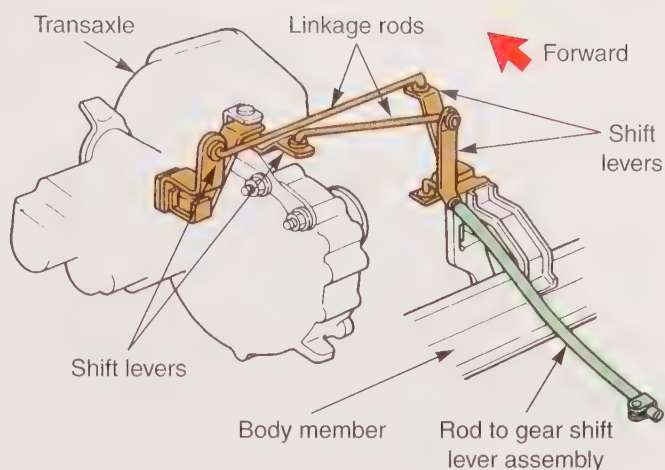


Figure 10-15. A single rod extends from the shift mechanism at the gearshift lever assembly to linkage at the transaxle. The rod can move back and forth, and it can also rotate. This movement is transferred to the levers and rods mounted at the transaxle. (Chrysler)

manner as they are on a rear-wheel drive manual transmission. Washers and bushings are used to reduce wear. The linkage can be adjusted by threaded swivels on the shift rods. Cable linkages have adjustment mechanisms that resemble those used to adjust a clutch cable linkage. Some shift linkage systems have provisions for lubrication, but most do not.

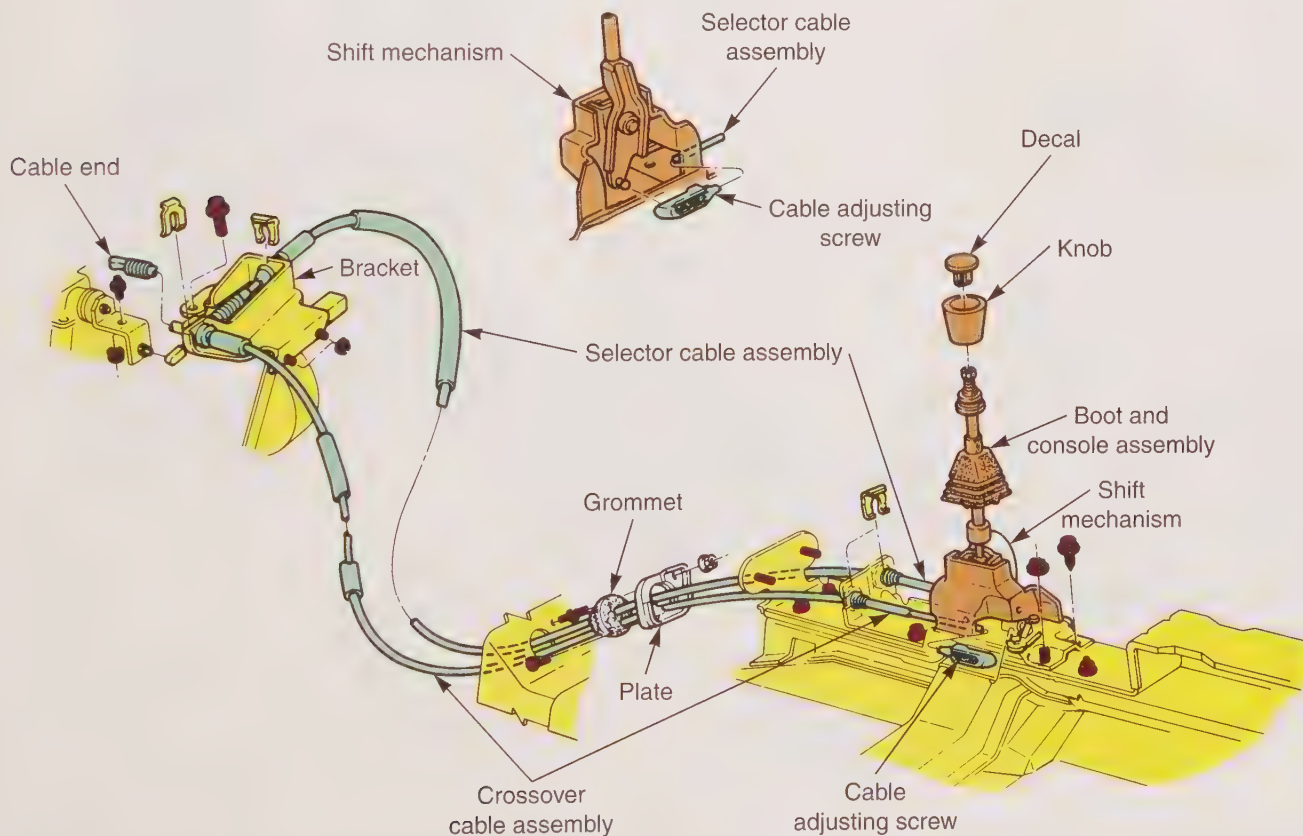


Figure 10-14. Study the cable type of shift linkage. The system shown has two sheathed cables that connect the gearshift lever to the transaxle internal shift linkage. (Chrysler)

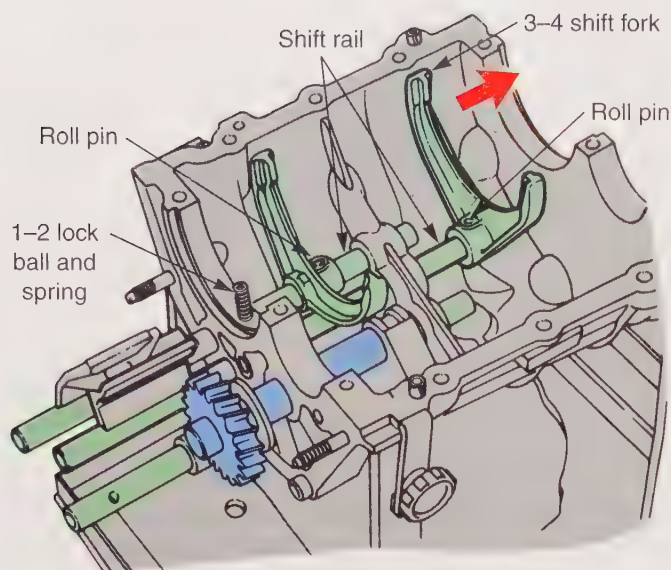


Figure 10-16. Some transaxle internal shift linkages use multiple shift rails. Notice the relative positions of the shift rails and shift forks inside a transaxle case. (Chrysler)

Internal shift linkage

The shift fork is operated inside the transaxle by a series of levers or more often, by a shifter shaft or shift rails that slide in holes drilled in the case. See **Figure 10-16**. The shift rail system is used on many transaxles and transmissions. It consists of a series of rods (shift rails), which operate the shift forks. The rails move in a straight line. The shift forks are attached directly to the shift rails.

An exploded view of a shift rail system is shown in **Figure 10-17**. This system has four shift forks, which are used to select the transaxle's six forward gears and one reverse gear. Notches seen along the shift rails are for detents. These spring-loaded devices keep the levers and, therefore, the fork and synchronizer sleeve in position when they are not being moved by the driver. •

Note that one kind of detent is inside a separate cover, which is installed in the case with a snap ring, **Figure 10-18**. This design serves the same purpose as other detent systems, but it can be serviced from outside the case.

Manual Transaxle Differential Assembly

The transaxle differential assembly is the part of the transaxle that allows the front wheels to turn at different speeds when the vehicle is turning a corner. The action of

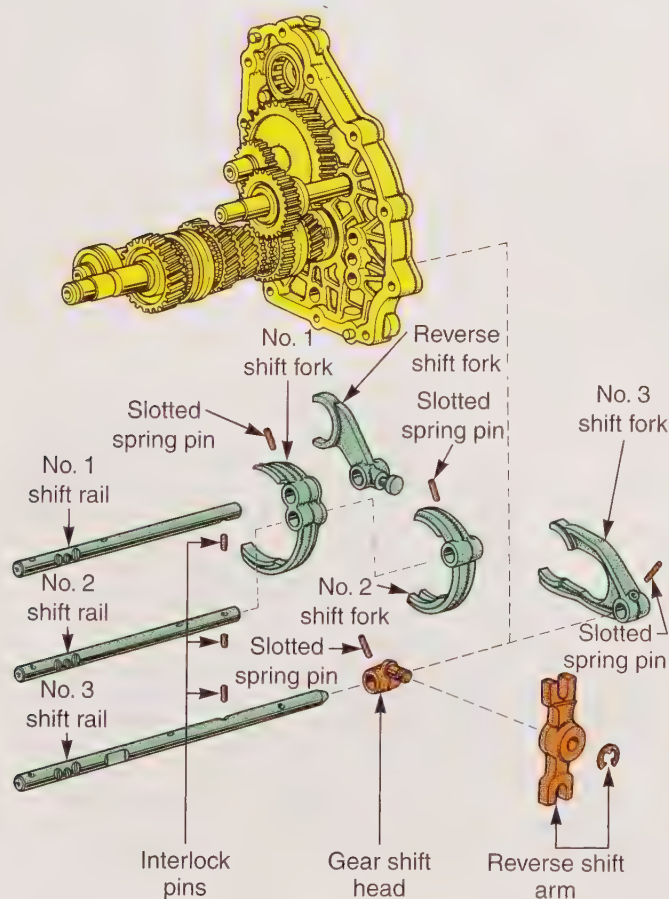


Figure 10-17. An exploded view of a shift rail system. Interlock pins make it impossible to move more than one rail at a time. This ensures that only one gear can be engaged during a shift. (Toyota)

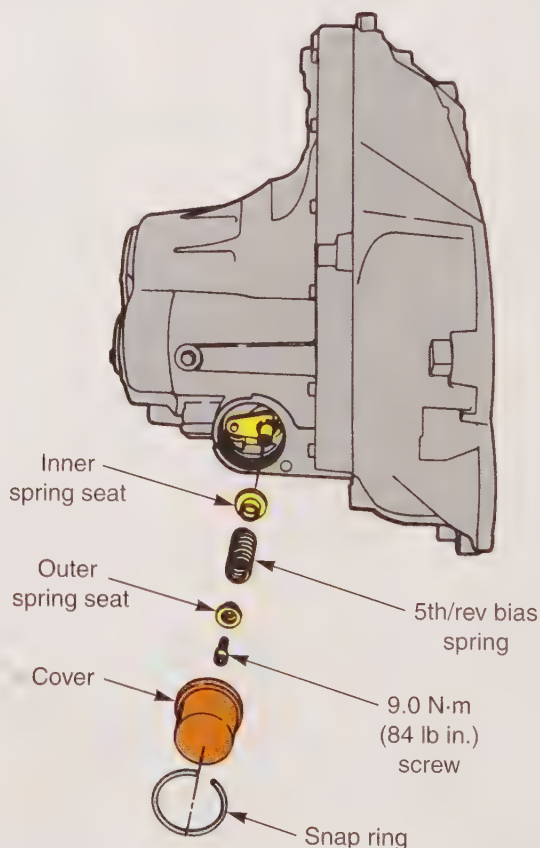


Figure 10-18. Detents fit into notches on the shift rails to keep the shift forks and shift rails in place once the desired gear is selected. The spring puts pressure on the shaft to keep it in place. (General Motors)

the differential assembly is the same as that of a rear axle assembly. When the vehicle makes a turn, the differential assembly allows the outer wheel to travel further than the inner wheel. This is necessary because the arc (or radius) of the turn is always greater at the outer wheel. If the axles were simply connected together, both wheels would be forced to rotate the same amount during a turn. To do this, one of the wheels would have to lose traction to make the turn. The transaxle differential assembly allows the vehicle to make turns without wheel hop. For further discussion on the general construction and operation of differential assemblies, refer to Chapter 16.

Differential drive gears are used in all transaxle differential assemblies. This gearset typically consists of helical ring and pinion gears. However, some transaxle designs have a hypoid ring and pinion to divert power flow by 90°. The drive pinion gear is on the transaxle output shaft. It meshes with the ring gear on the differential case.

The transaxle differential assembly is also composed of meshing spider and side gears, enclosed in a differential case. **Figure 10-19** is an exploded view of a typical transaxle differential assembly. The differential case is a one-piece unit made of cast iron or aluminum. The ring gear is bolted to the case. It meshes with the drive pinion gear,

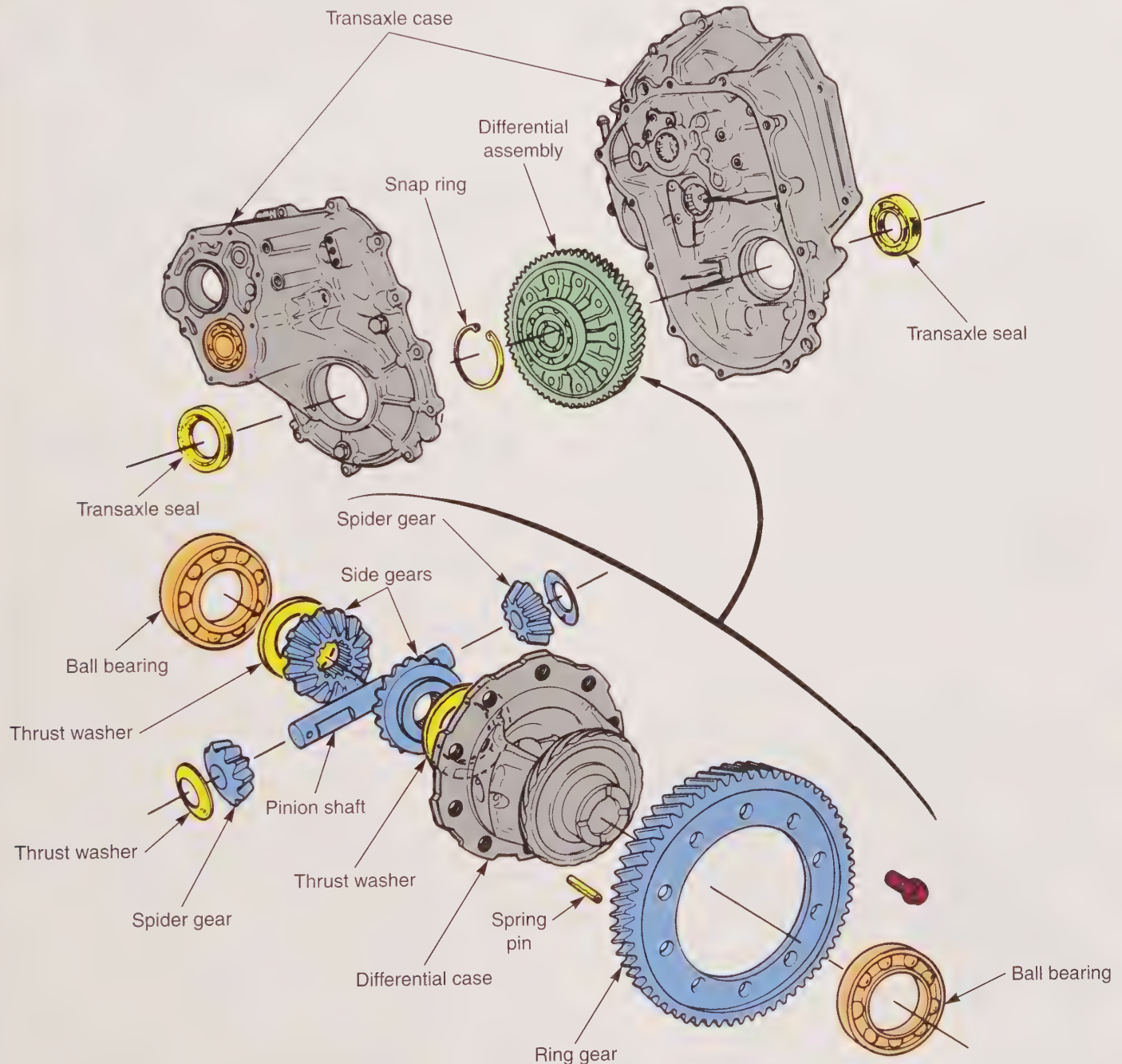


Figure 10-19. This exploded view of a transaxle differential shows the relative positions of the various components. Note the likeness of this differential to that of a rear-wheel drive vehicle. This transaxle is unusual in that it uses ball bearings for side bearings. (Honda)

which is located on the output shaft of the transaxle transmission. The number of teeth on the ring and pinion gears determines the final drive ratio of the transaxle.

The differential assembly shown in **Figure 10-20** illustrates nonidentical side gears found on many transaxle differential assemblies. Since the CV axles are of different lengths or may have an intermediate shaft, different side gear designs may provide the most efficient way to transfer power. This is the main visual difference between many transaxle differentials and differential assemblies used on rear-wheel drive vehicles.

The differential assembly is often lubricated with the same oil used to lubricate the transmission gears. Some differentials, especially the hypoid types used with longitudinal engines, may have a separate lubrication sump. This type of differential usually uses a heavier grade of gear oil than the transmission does.

Manual Transaxle Case

The manual transaxle case protects and aligns the gears and other moving parts. The transaxle case also contains transaxle lubricant and keeps dirt and water out of the gears and bearings. The inboard ends of the CV axles and the stationary parts of the transmission are mounted on the case. Most of the bearings that support the gear and axle shafts are mounted in the case.

There may be one or more sheet metal or cast aluminum access covers on the transaxle case. These can be removed for servicing the transaxle. In some instances, these covers can be removed to service certain internal parts without removing the transaxle from the vehicle. Many transaxle cases are designed in two pieces. When the transaxle requires service, the case can be split to gain access to the internal parts.

Most manual transaxle cases of front-wheel drive vehicles are made of aluminum. The case is machined to

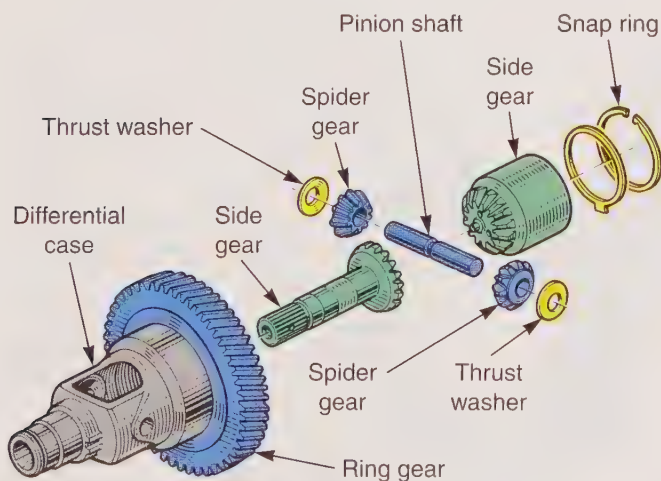


Figure 10-20. This exploded view of a differential assembly shows the differences that can exist between side gears. The side gears have the familiar beveled-cut teeth, designed to mate with the beveled spider gear teeth. (Chrysler)

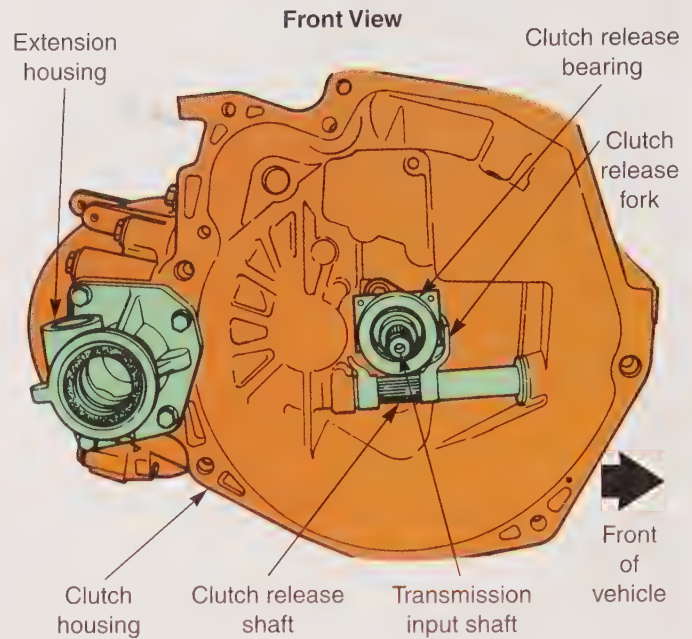


Figure 10-21. This is the front view of a popular make of manual transaxle used with a transverse engine. The clutch housing is integral with the transaxle case. It is machined to precisely fit the rear of the engine. Note the clutch release (throwout) bearing, clutch release shaft and fork, and input shaft. The extension housing contains an opening for one of the CV axles. (Chrysler)

precisely fit the rear, or output end, of the engine and to accept the internal and external transaxle parts, **Figure 10-21**. A spacer plate may be installed between the transaxle and engine to strengthen the assembly. This is often done when the transaxle is the mounting surface for the engine starter.

The clutch housing is usually cast as an integral part of the transaxle case. Further, the housing for the differential portion of the transaxle is usually an integral part of the case. Some differentials, however, especially those on transaxles with conventionally mounted engines, have separate housings. This allows for easier service of the internal parts. Many separate differential housings are made of cast iron for added strength.

Figure 10-22 shows three other views of the manual transaxle featured in **Figure 10-21**. Notice that the housing for the differential assembly is integral with the case, just as the clutch housing is. This particular case has two sheet metal covers, which can be removed to service the transaxle internal parts. Among other items, the case contains a lubricant fill plug and vent.

Note that the openings in the transaxle case for the input shaft and CV axles are equipped with lip seals. These are used for preventing lubricant leakage. Stationary parts, such as the transaxle case halves or covers, are sealed with gaskets. Openings in the case for speedometer, linkage, switches, and other parts may be sealed when these components are threaded into the case. In some instances, O-rings may be used on such components to help provide a tight seal.

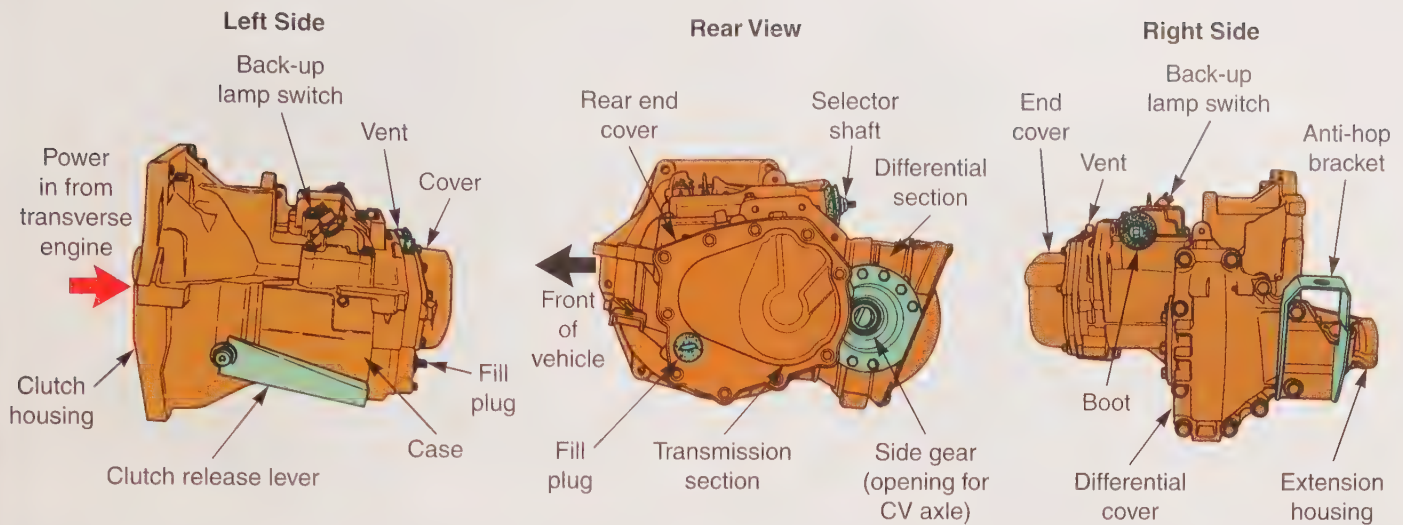


Figure 10-22. These views of the previously illustrated transaxle show various other features of the case. (Chrysler)

Manual Transaxle Power Flow

Power flow through a transaxle mounted on a transverse engine runs parallel with the crankshaft. There is no change in angle once power leaves the engine. Engine power enters the input shaft of the transaxle transmission. Power is engaged and disengaged through the clutch assembly. The input shaft drives the output shaft through the shaft gearsets. The drive pinion gear, located on the end of the output shaft, drives the ring gear on the differential case. From the ring gear, power enters the spider and side gears and exits through the CV axles to the front wheels.

On a transaxle attached to a longitudinal engine, power flow must make a right-angle turn at the differential assembly, as it does in a rear-wheel drive vehicle. This type of transaxle essentially has two input shafts. One shaft delivers power from the clutch to a drive chain. The drive chain then drives the input shaft of the transaxle. The input shaft runs parallel to the clutch shaft. (Refer back to **Figure 10-5.**) Note that some transaxles of this type use two large gears instead of a drive chain to transfer power to the transaxle input shaft.

With this arrangement, power flow then enters a countershaft through the shaft gearsets. The countershaft drives a third transaxle shaft—the output shaft. The output shaft drives the differential pinion gear, which is attached to the end of the output shaft. The pinion gear drives the differential ring gear and case assembly. The ring and pinion is the hypoid type, like the ones used on front-engine, rear-wheel drive vehicles. The design causes the power flow to make a 90° turn. From the differential side gears, power exits through the CV axles to the front wheels. Note that this type of transaxle more closely resembles the rear-wheel drive manual transmission.

Detailed Look at Power Flow

A detailed look at power flow through a transaxle used with a transverse engine is illustrated in **Figures 10-23** through **Figure 10-28**. This transaxle is a model with a basic two-shaft (input and output) arrangement. It is used with a transverse engine.

Figure 10-23 shows the gears in Neutral. The clutch is engaged and is turning the input shaft, but power is not transmitted to the output shaft. The gears on the output shaft are turned by those on the input shaft, but both synchronizers are centered. The synchronizers must be moved off center to engage the gears riding on the output shaft with the shaft itself.

In **Figure 10-24**, the transaxle is in first gear. The rear synchronizer remains centered. The front synchronizer has been moved toward the front of the transaxle, engaging first gear on the output shaft with the shaft itself. Power

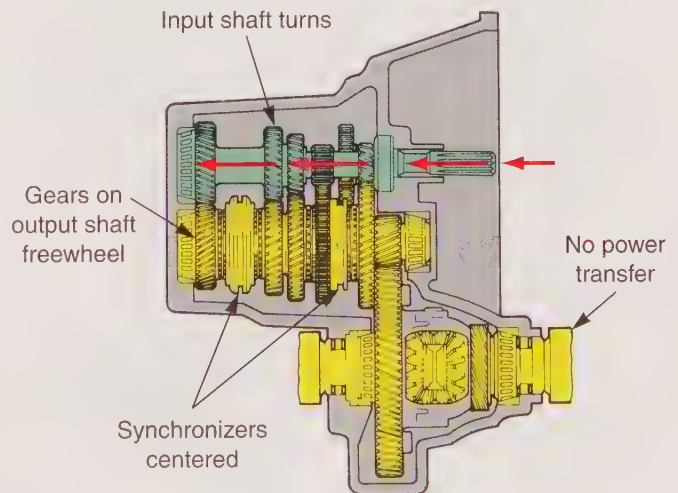


Figure 10-23. Power flow through a typical transaxle mounted on a transverse engine is shown here in Neutral. (Ford)

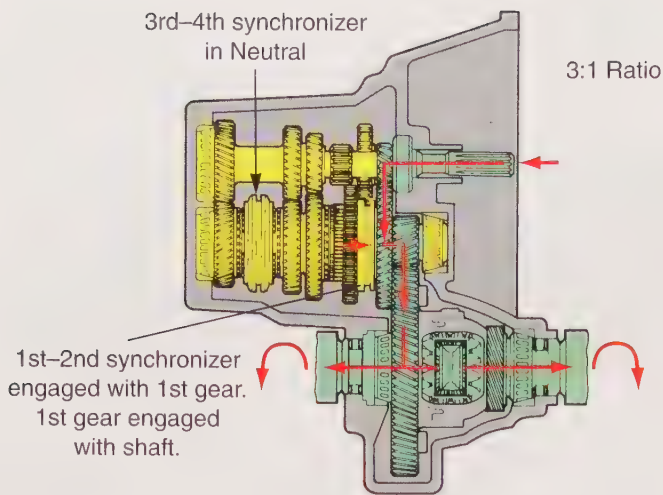


Figure 10-24. Power flow is depicted with the same transaxle in first gear. (Ford)

flows through the input shaft to the first gear on the input shaft. From here, it flows to the first gear on the output shaft, through the shaft to the differential drive pinion gear, and on to the ring gear. The number of teeth on these particular input and output shaft gears produces a 3:1 ratio in first gear. From the ring gear, power flows through the differential case assembly and out to the front wheels through the CV axles.

Figure 10-25 shows the transaxle in second gear. The rear synchronizer is centered. The front synchronizer has been moved toward the rear of the transaxle, connecting second gear on the output shaft with the shaft itself. Power flows through the input shaft, to the output shaft, through the differential drive gears and case assembly, and out through the CV axles. A gear ratio of 2.5:1 is achieved in second gear.

In **Figure 10-26**, the transaxle is in third gear. The front synchronizer is centered. The rear synchronizer has been moved toward the front of the transaxle, connecting the third gear output shaft gear with the output shaft. Power

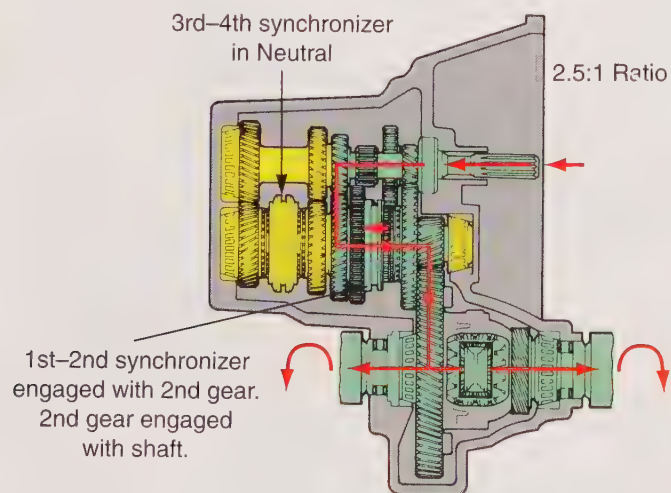


Figure 10-25. This illustration shows power flow through the same transaxle in second gear. (Ford)

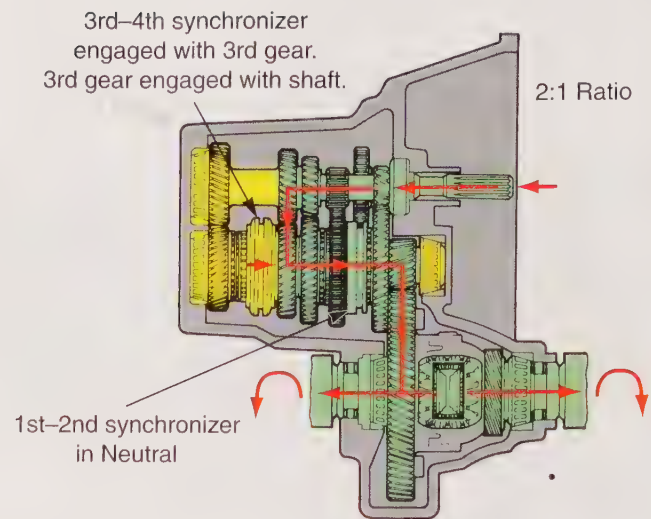


Figure 10-26. Power flow is shown here with the transaxle in third gear. (Ford)

flows through the input shaft third gear to the output shaft third gear to drive the output shaft. From the differential pinion gear, power flows to the ring gear and differential case assembly. A gear ratio of 2:1 is achieved.

Fourth gear is shown in **Figure 10-27**. The front synchronizer remains centered, while the rear synchronizer is pushed back to connect fourth gear on the output shaft with the shaft itself. Since the particular input and output shaft gears have the same number of teeth, a gear ratio of 1:1, or direct drive, is achieved. Power flows through the gears to the pinion and ring gears and out of the differential assembly to the CV axles and front wheels.

Reverse is shown in **Figure 10-28**. Both synchronizers remain centered as the reverse idler gear slides into position to connect the input and output shafts. The idler gear causes the output shaft to rotate in the opposite direction, causing the differential side gears and CV axles to turn backward.

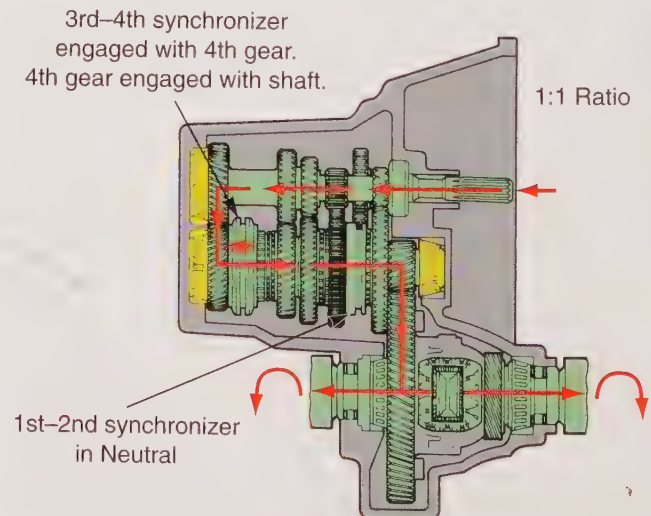


Figure 10-27. This shows power flow through the transaxle in fourth gear. (Ford)

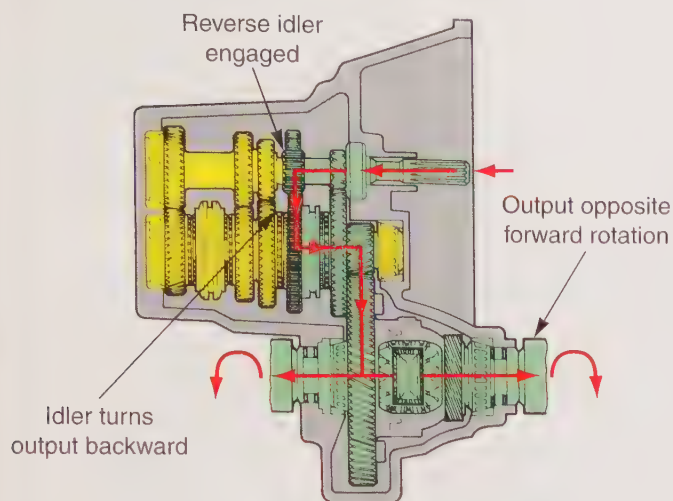


Figure 10-28. In Reverse, the reverse idler gear is engaged. It causes the output shaft and differential assembly to turn in the reverse direction. (Ford)

Manual Transaxle Designs

Although manual transaxles are similar in their basic design, many minor differences exist between models. Some of these differences may be seen by examination of **Figures 10-29** through **10-31**.

A typical General Motors manual transaxle for use with transverse engines is shown in **Figure 10-29**. This particular transaxle has five forward speeds, all synchronized.

Figure 10-30 shows a 4-speed manual transaxle used on many DaimlerChrysler front-wheel drive vehicles with transverse engines. It is fully synchronized in all forward gears. Note the selector shaft extending through the top of the case. It operates the shift rails. Also note the unusual location of the clutch release bearing. The clutch pushrod extends through the center of the input shaft to actuate the clutch.

The Ford transaxle shown in **Figure 10-31** has an overdrive fifth gear. The input shaft contains a cluster gear, which is integral with the shaft. Synchronizers are not used on the input shaft of this design, whereas they were on the previous two-transaxle designs.

Rear-Wheel Drive Transaxle

The most well-known rear-wheel drive transaxles were the original Volkswagen Beetle and the Chevrolet Corvair. At one time, these vehicles were common, but both are now out of production. Transaxles are still occasionally used on modern rear-wheel drive vehicles—some Porsche models, for example. The internal design and construction of rear-wheel drive transaxles is similar to that of those used on front-wheel drive vehicles. The major classes of rear-wheel drive transaxles are those installed with a rear engine and those used on a front-engine vehicle.

A typical rear-wheel drive manual transaxle used with a rear-mounted engine is shown in **Figure 10-32**. With this construction, the engine is placed at the extreme rear of the vehicle and power flows forward to reach the transaxle. After passing through the transaxle, the power flow exits to the rear drive wheels.

A typical transaxle used with a front-engine, rear-wheel drive vehicle is shown in **Figure 10-33**. The clutch, as well as the transaxle transmission and differential assembly, is mounted in a single housing. The transaxle receives its power from a drive shaft that is connected to the front-mounted engine.

Summary

Transaxle construction and operation is similar to that of manual transmissions and differential assemblies used in rear-wheel drive train vehicles. The transaxle has the transmission and differential contained in one case. Transaxle design and power flow varies according to how the engine is placed in the vehicle. Transverse engines use a transaxle that allows power to flow in a straight line, without changing angles. The transaxle used in a vehicle with a longitudinal engine more closely resembles a rear-wheel drive manual transmission. There is usually a drive chain or

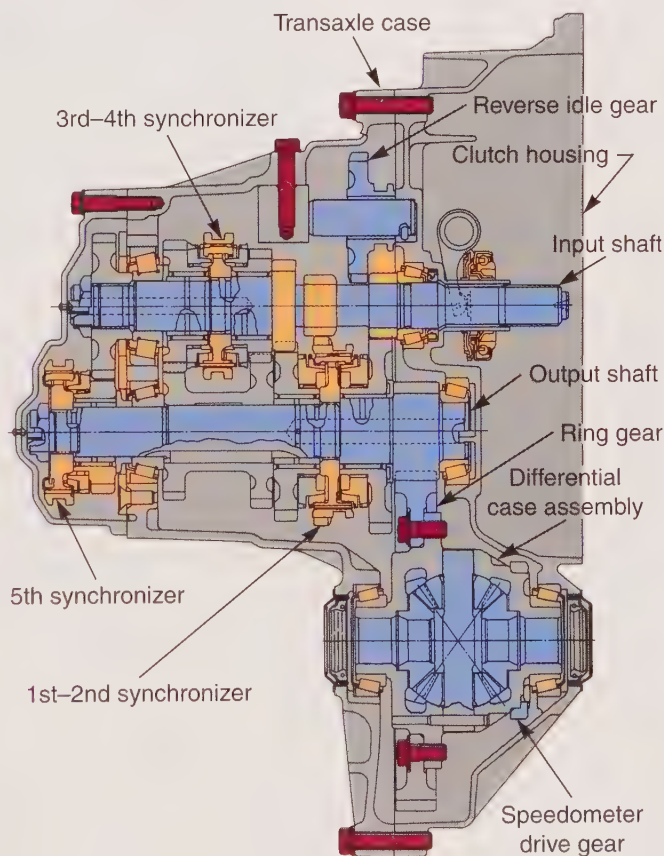


Figure 10-29. This 5-speed transaxle is used with transverse engines. (General Motors)

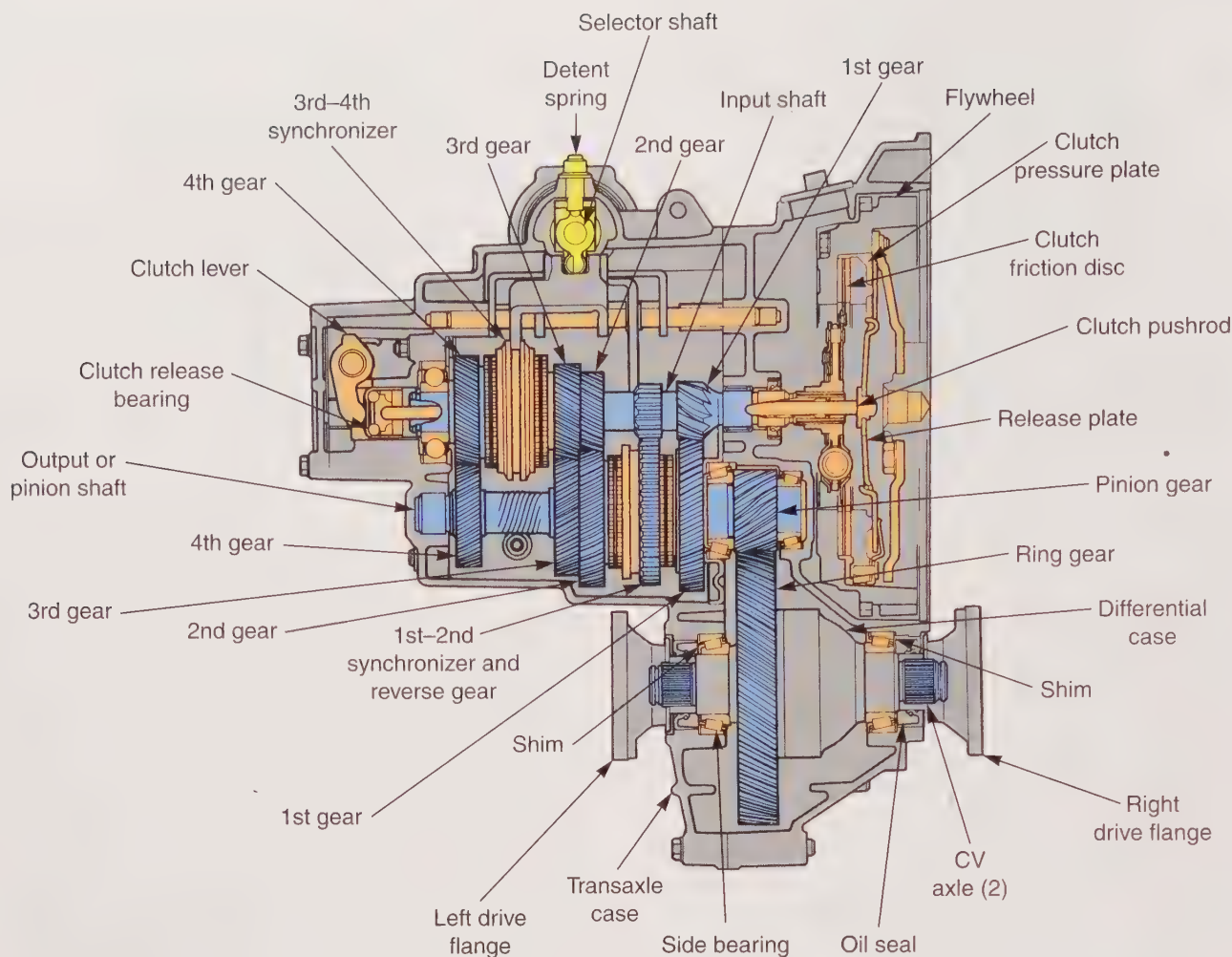


Figure 10-30. A 4-speed transaxle used with transverse engines is shown here. This transaxle has a unique feature in the position of the clutch release bearing. (Chrysler)

gears to connect the input shaft and clutch. This type of transaxle uses hypoid ring and pinion gears.

Many of the manual transaxle transmission parts are similar to those used in a manual transmission. Major transmission shafts of the typical transaxle include an input shaft and a countershaft that serves as the output shaft. The differential pinion gear is on the end of the output shaft. Synchronizers and shift forks operate just as they do in rear-wheel drive transmissions.

All transaxles have a ring and pinion gearset. On transaxles used with transverse engines, the ring and pinion are straight-cut or helical gears. If the transaxle is used with a longitudinal engine, the ring and pinion are

a hypoid set. The difference in the number of teeth in the ring and pinion determines the final drive ratio.

The shift linkage consists of a series of links, levers, rods, and sometimes, cables, which allow the driver to select gears. Moving the floor-mounted lever allows the external shift linkage to move shift rods and forks inside the transaxle case. These rods and forks move the synchronizers.

The main stationary parts of the transaxle are the case and covers. The case is made of cast aluminum. The case may be a one-piece unit, or it may be designed to be split apart for service. The covers are made of sheet metal or cast aluminum. They cover various operating parts of the transaxle and are designed to be removed for transaxle service.

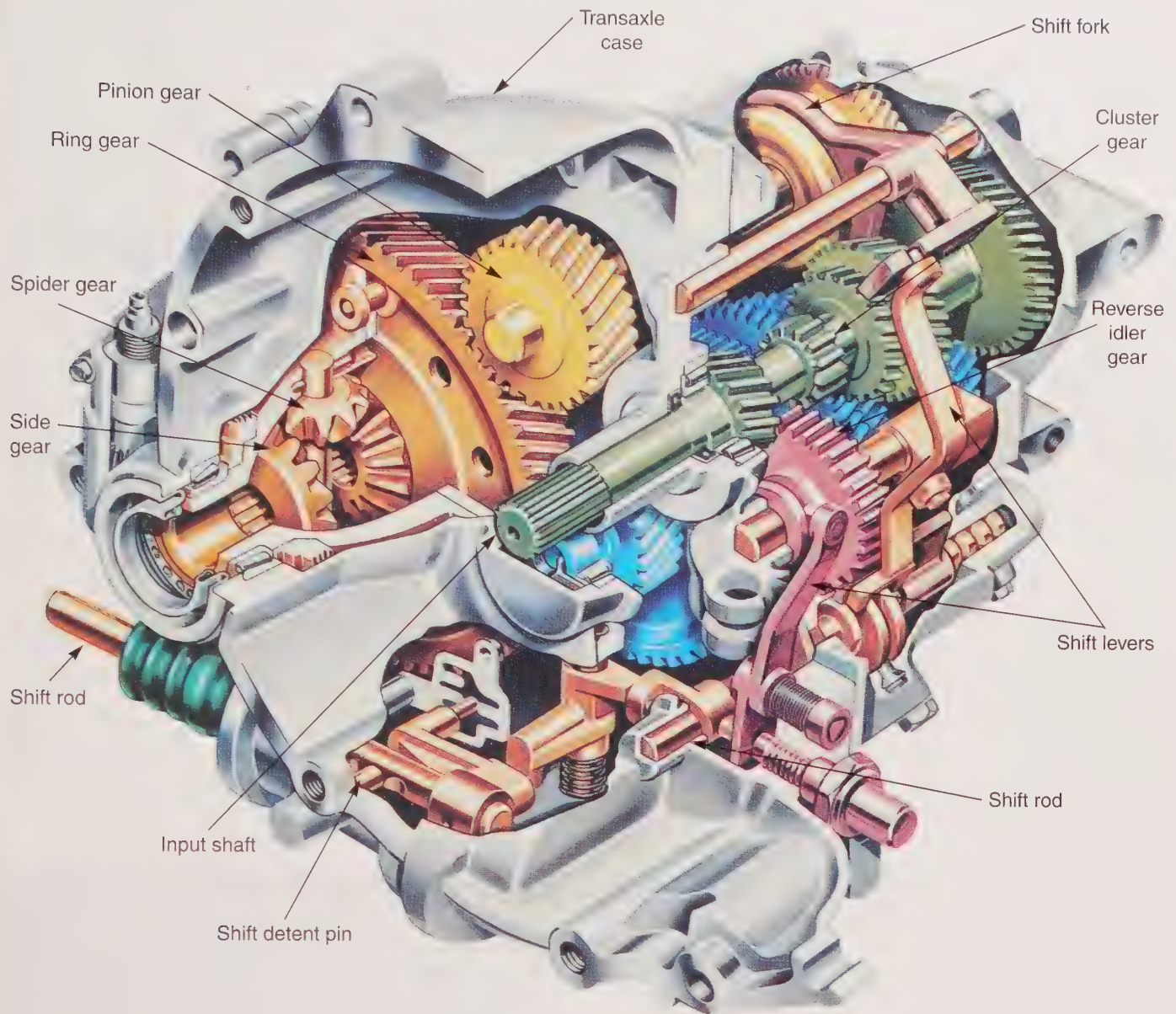


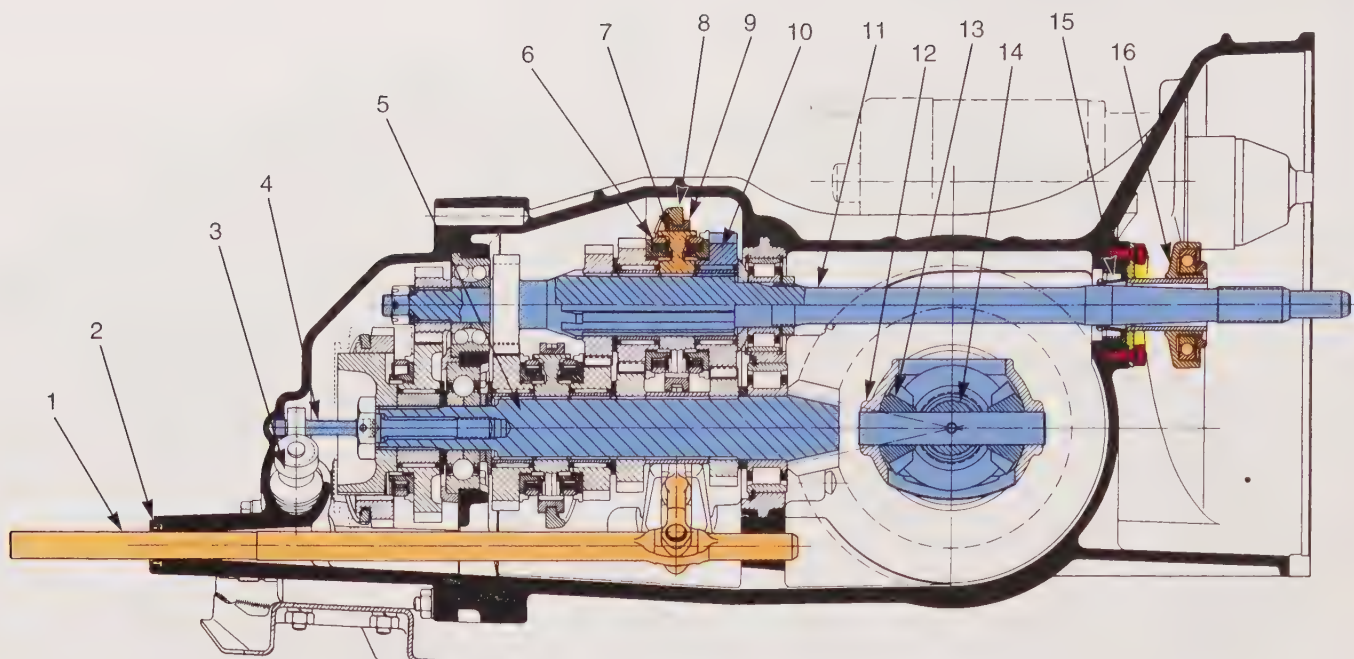
Figure 10-31. This cutaway shows the inside of a 5-speed manual transaxle with overdrive. (Ford)

Review Questions—Chapter 10

Answer the following questions using the information provided in this chapter.

1. The _____ portion of the transaxle allows the vehicle to make turns while power is delivered.
2. List and explain the seven major parts of a manual transaxle.

3. Which one of the following is made to slip into a groove that runs radially around the outer sleeve of the synchronizer?
 - (A) Shift linkage.
 - (B) Shift fork.
 - (C) Synchronizer inner hub.
 - (D) Synchronizer blocking ring.



Cross-Section View of Transmission and Differential

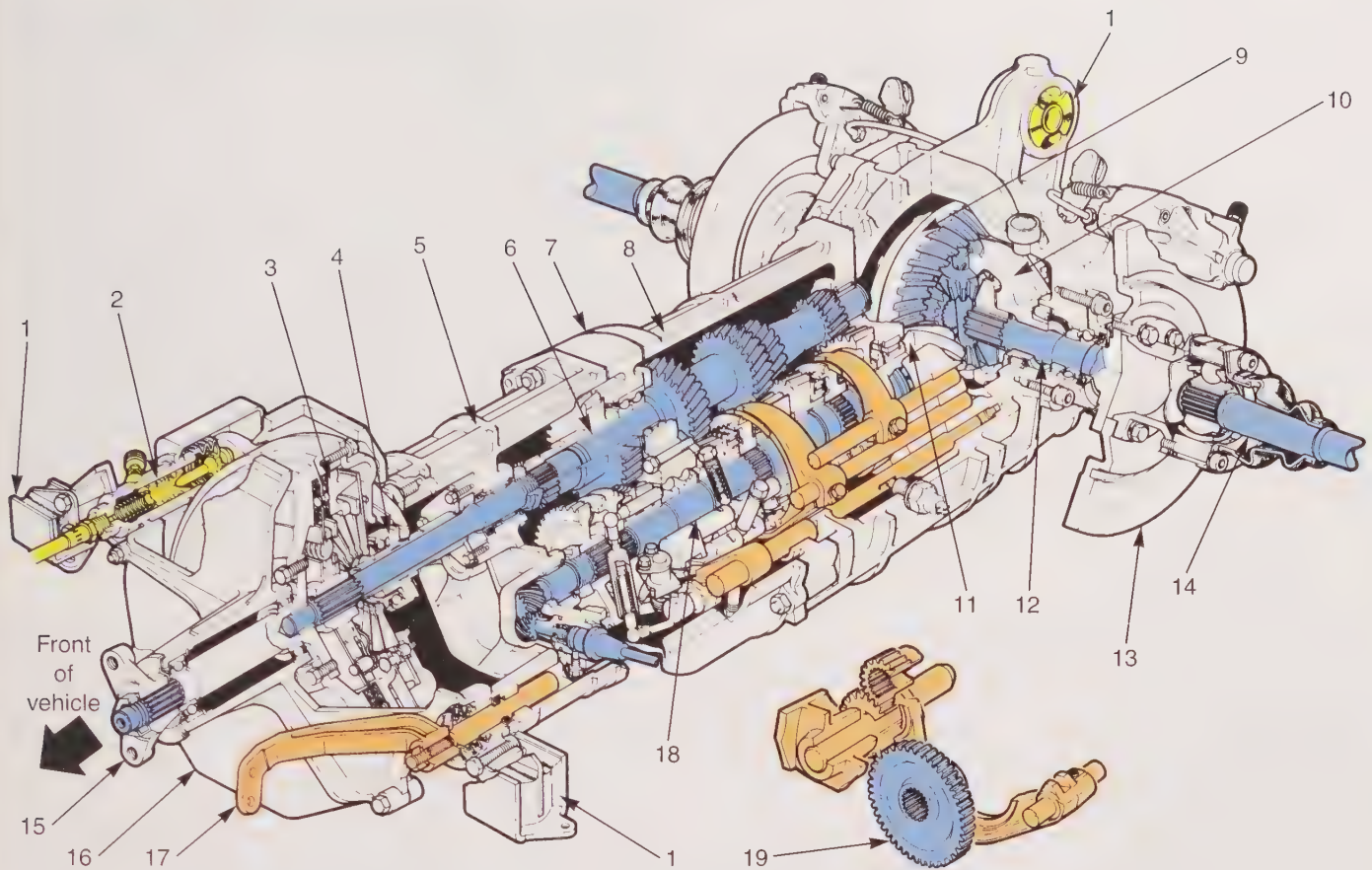
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|-----------------------|-------------------------------|------------------------------|-----------------------------|
| 1. Shift rod | 5. Pinion shaft | 9. Synchronizer outer sleeve | 13. Bevel spider gear |
| 2. Shift rod oil seal | 6. Synchronizer blocking ring | 10. Gear 1, 5th speed | 14. Side gear shaft |
| 3. Tachometer drive | 7. Spider | 11. Input shaft | 15. Input shaft oil seal |
| 4. Gear shaft | 8. Shift fork | 12. Differential case | 16. Clutch throwout bearing |

Figure 10-32. Study the rear-engine transaxle. On this design, the engine is installed at the rear of the vehicle and power comes forward to enter the transaxle. (Porsche)

4. The only place synchronizers are *not* found in a typical transaxle is _____.
 - (A) first gear
 - (B) direct drive
 - (C) overdrive gear
 - (D) reverse gear
5. Explain a shift rail system.
6. A(n) _____ is a spring-loaded holding mechanism.
7. With a(n) _____ engine, the transaxle's input shaft centerline aligns with the crankshaft centerline.
8. How are differential gears lubricated?
9. In your own words, describe the power flow through a typical manual transaxle mounted on a transverse engine.
10. The shaft arrangement in a transaxle attached to a _____ mounted engine is similar to that found in a manual transmission.

ASE-Type Questions—Chapter 10

1. The drive train of a front-wheel drive vehicle, as compared to that of a rear-wheel drive vehicle, eliminates the need for each of the following *except*:
 - (A) rear axle housing.
 - (B) transmission hump.
 - (C) drive shaft assembly.
 - (D) differential unit.
2. The basic construction of a transaxle in any front-wheel drive vehicle depends on _____.
 - (A) presence or absence of a differential assembly
 - (B) gear ratio
 - (C) engine placement in the vehicle
 - (D) how power flows through the transaxle

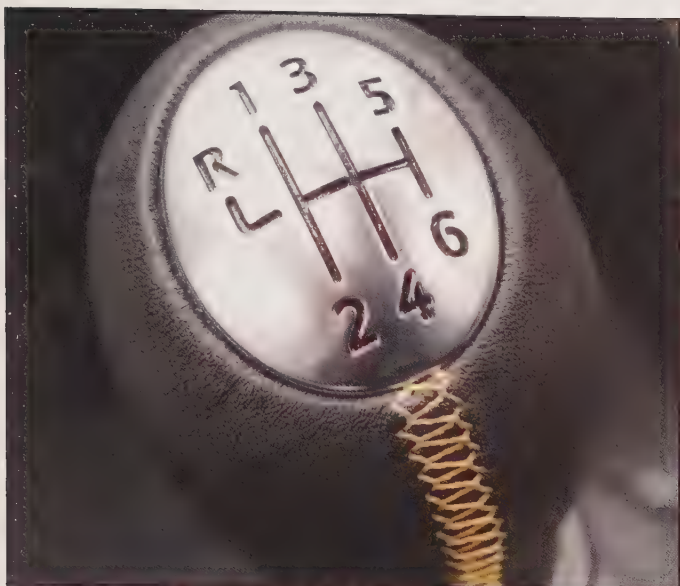


- | | | |
|-----------------------------|---------------------------------|---|
| 1. Anti-vibration mountings | 8. Gearbox-differential housing | 15. Universal joint yoke connecting clutch shaft to propeller shaft |
| 2. Clutch slave cylinder | 9. Crown or ring wheel | 16. Clutch housing |
| 3. Clutch plate | 10. Differential case | 17. Rear gear change lever |
| 4. Release bearing | 11. Drive pinion gear | 18. Pinion shaft |
| 5. Clutch-gearbox housing | 12. Differential output shafts | 19. Reverse gear components |
| 6. Mainshaft | 13. Brake disc | |
| 7. Intermediate flange | 14. Drive shaft | |

Figure 10-33. This is a rear-mounted transaxle used on a front-engine vehicle. Power is delivered to the transaxle through a drive shaft ahead of the clutch assembly. (Alfa Romeo)

3. Manual transaxle shafts include each of the following *except*:
 - (A) stator shafts.
 - (B) input shafts.
 - (C) output shafts.
 - (D) reverse idler shafts.
4. Gears of the transaxle transmission are used for each of the following *except*:
 - (A) distributing oil.
 - (B) transmitting power.
 - (C) traction control.
 - (D) backing up a vehicle.
5. Before freewheeling gears can be locked to the turning shaft on which they ride, they must turn at almost the same speed as the shaft. Technician A says that the combined power of input and output shafts achieves this. Technician B says that this is accomplished through the synchronizers. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

6. Each of the following is a function of the manual transaxle *except*:
 - (A) diverting power flow from the transverse engine by 90°.
 - (B) selecting the proper gear ratio or reverse.
 - (C) allowing the vehicle to make turns.
 - (D) transferring engine power to the drive axles.
7. A shift fork is made to slip into a groove cut into the outer sleeve of the _____.
 - (A) drive chain
 - (B) input shaft
 - (C) synchronizer
 - (D) gear bushing
8. Components involved in shifting a manual transaxle include each of the following *except*:
 - (A) the spacer plate.
 - (B) synchronizers.
 - (C) the gearshift lever.
 - (D) shift rails.
9. Differential case gears for front-wheel drive vehicles with transverse engines are typically driven by _____.
 - (A) chain drives
 - (B) helical ring and pinion gears
 - (C) hypoid ring and pinion gears
 - (D) worm gears
10. Each of the following functions is served by the manual transaxle case *except*:
 - (A) protecting gears.
 - (B) aligning moving parts.
 - (C) enclosing the clutch.
 - (D) holding transaxle lubricant.
11. Power flow to the manual transaxle is engaged and disengaged by means of the _____.
 - (A) CV axles
 - (B) clutch assembly
 - (C) drive shaft assembly
 - (D) differential assembly
12. A manual transaxle used with a longitudinal engine will have which one of the following at the end of the output shaft?
 - (A) Drive chain.
 - (B) Reverse gear synchronizer.
 - (C) Hypoid ring and pinion gearset.
 - (D) CV axles.



Chapter 11

Manual Transaxle Problems, Troubleshooting, and Service

After studying this chapter, you will be able to:

- ☐ Name and describe common problems that can occur in a manual transaxle.
- ☐ Remove a manual transaxle from a vehicle.
- ☐ Disassemble a manual transaxle.
- ☐ Inspect the parts of a manual transaxle.
- ☐ Assemble a manual transaxle.
- ☐ Install a manual transaxle in a vehicle.

Technical Terms

Lubricant leakage

No-drive condition

Hard shifting

Gear jumpout

Gear slipout

Gear clash

Abnormal noise

Introduction

Since most cars and some trucks use front-wheel drive, manual transaxles are common. Manual transaxles come in varying designs, with four, five, or six forward gears. The modern automotive technician should know how to diagnose and repair the different kinds of manual transaxles.

This chapter is a general guide to manual transaxle diagnosis and repair. Building on the knowledge you gained from previous chapters, the information in this chapter will help you understand the transaxle diagnostic information contained in the manufacturer's service information. If you study the information presented here, you will know the general techniques for servicing all types of manual transaxles. **Figure 11-1** shows typical transaxle problems. Study them carefully.

Manual Transaxle Problems and Troubleshooting

If you do not know what is wrong with a transaxle, how can you fix it? You must become skilled at finding out what the problem is before beginning repairs. This section is designed to make transaxle troubleshooting easier.

Since transaxles consist of mechanical parts, most manual transaxles wear out eventually. Often, this is because of high vehicle mileage. Sometimes, however, transaxles require repair at low mileage because of careless driving habits. For example, changing gears too quickly, downshifting at high speeds, or releasing the clutch pedal before gears are completely engaged can damage the transaxle. These actions can chip or break teeth on the transaxle transmission gears or damage the synchronizers.

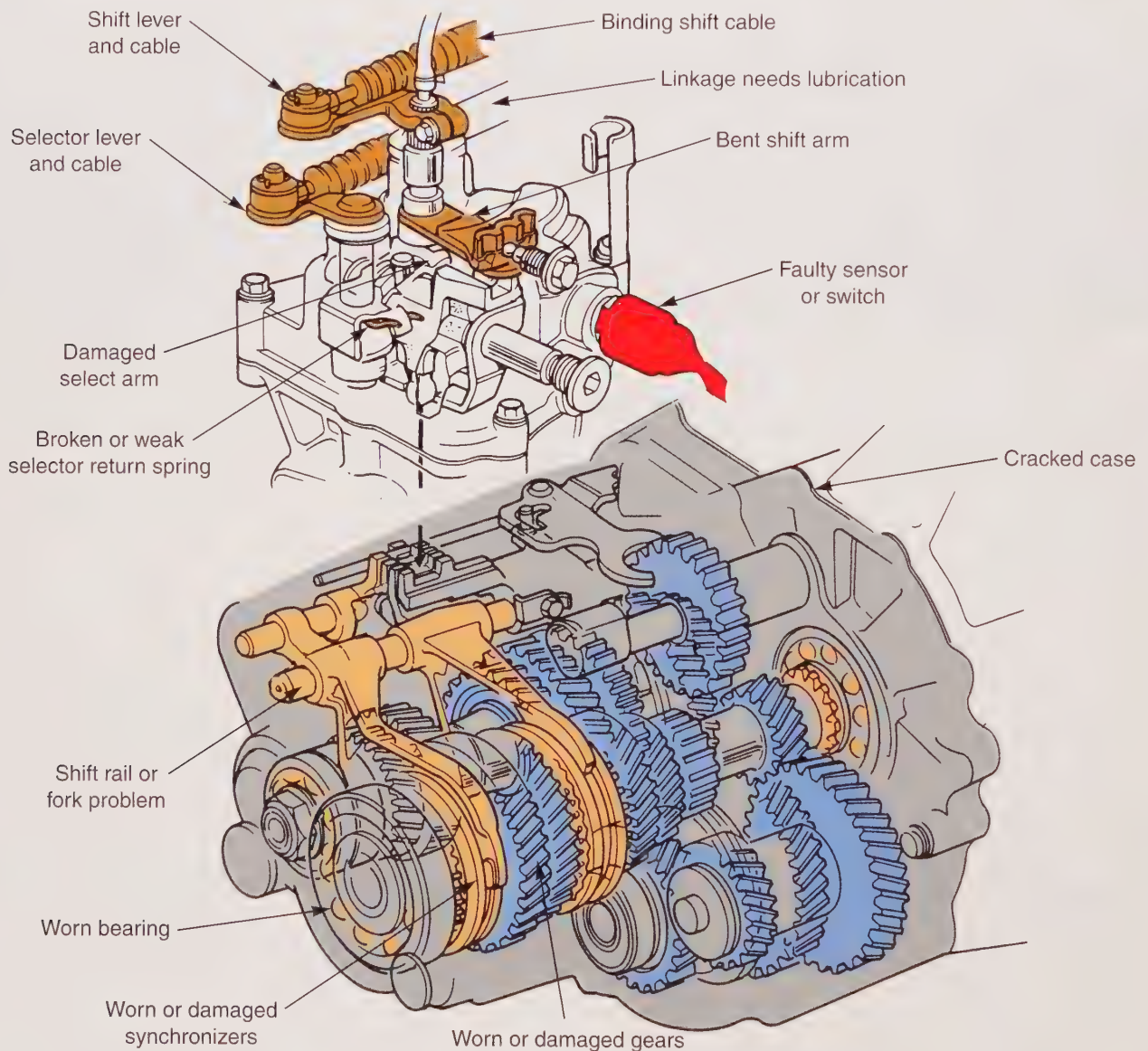


Figure 11-1. This figure illustrates some of the problems that can affect a typical manual transaxle. These problems can be diagnosed using logical troubleshooting techniques. Note that the selector cable transmits right and left movements of the gearshift lever to the shift forks. The shift cable transmits fore and aft movements of the gearshift lever. (Honda)

Low fluid level or water contamination can also cause harm to the transaxle. If the transaxle lubricant level becomes too low, moving parts will wear prematurely. If the vehicle is driven through deep water, the water can enter the transaxle through the vent. Water will contaminate the oil. As a result, the gears and bearings may be destroyed through pitting and poor lubrication.

Always begin diagnosing manual transaxle problems by finding out why the vehicle was brought in for service. Get the customer to describe the transaxle problem. When test-driving a vehicle, determine in what gear and at what speed the problem occurs. If possible, take the customer with you and have him or her point out the particular problem while it occurs.

During a road test, try to isolate transaxle problems from CV axle, engine, tire, and other vehicle problems. For example, rumbling or roaring noises that increase and decrease with road speed are usually caused by bad wheel bearings or defective tires. Vibrations that cycle according to vehicle speed are usually caused by faulty CV axles. Slippage is caused more often by the clutch than the transaxle. Problems that seem to occur in one gear only are usually caused by the transaxle itself.



Warning: When road testing a vehicle, *always* obey all traffic regulations. Also, try to choose roads that are not congested or empty parking lots for testing. Do not become so engrossed in diagnosing the transaxle that you end up having an accident.

Once you have identified the problem, check out the cause with the easiest solution first; you should always proceed from easiest to hardest. Consider all possible causes, even the most unlikely.

Many manual transaxle problems can be solved by simple linkage adjustments or by adding transaxle lubricant. Every manual transaxle that is brought in for service should have its clutch and shift linkage adjusted and its fluid level checked. A manual transaxle may have a dipstick or just a fill hole for checking the level. If needed, the proper grade and type of oil should be added, **Figure 11-2**. If the oil level is low, check for leaks.



Note: If the transaxle has a separate reservoir for differential lubricant, the fluid level in this reservoir should also be checked.

Common problems encountered in the manual transaxle are similar to those seen in the manual transmission and rear axle assembly. Some of these problems and their possible solutions are presented in the following sections.

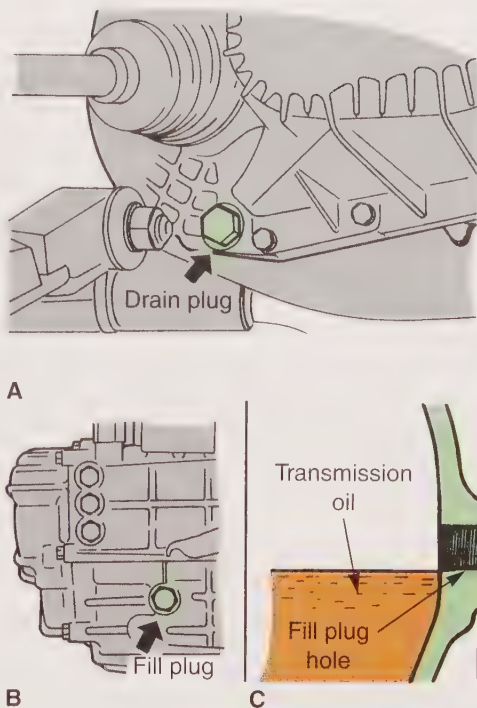


Figure 11-2. Transaxle lubricant levels must be maintained to prevent severe damage. Some transaxles must have lubricant changed periodically. Consult the manufacturer's service manual for instructions on how to check the level and to ensure you use the right kind of lubricant. A—Typical drain plug location. B—Typical fill plug location. C—Lubricant level should just wet the bottom of the fill plug threads. (Chrysler)

Lubricant Leakage

Lubricant leakage is an unwanted loss of lubricant from the transaxle. Transaxle lubricant levels may drop slightly over long periods of time because of evaporation. If the lubricant level is very low, the transaxle is probably leaking.

Always make sure the leak is actually coming from the transaxle. Engine oil, brake fluid, power steering fluid, or engine coolant could be dripping down onto the transaxle. If the transaxle case is wet but its oil level is normal, something else may be leaking.

Once you are sure the leak is coming from the transaxle, check to determine the location and cause. Transaxle leaks are most commonly found at the case and end cover gaskets. Sometimes the case or cover has been gouged or otherwise damaged. Other causes of leaks are bad CV axle or shift rail seals, lack of sealer on bolts, loose drain or fill plugs, and cracks in the transaxle case. Leaks are often caused by a high lubricant level in the transaxle. A high fluid level can cause oil to leak from good seals or from the transaxle vent.

If a seal or gasket is leaking, or if defects in other transaxle parts are causing the leak, the transaxle may have to be removed to gain access to the parts. The CV axles can usually be removed to replace the axle seals without removing the transaxle.

No-Drive Condition

A **no-drive condition** exists when engine power cannot be transmitted through the transaxle. The most common cause of a no-drive condition is a broken shaft or stripped gears on the input shaft. Sometimes, the transmission is locked in two gears and is unable to move. This is often a linkage problem. The linkage may be broken or disconnected and, therefore, may be unable to engage the gears, or there may be a problem with the linkage interlock.

If a shaft is broken or a gear is stripped, the engine runs easily with the clutch engaged in the particular gear. If the transmission is locked, engaging the clutch kills the engine. Most no-drive problems require the removal and disassembly of the transaxle.

Hard Shifting

Hard shifting occurs when the gearshift lever is difficult to move from gear to gear. Sometimes, the problem occurs in only one gear. In most cases, however, all gears will be difficult to select. The usual causes of hard shifting are bent or worn external shift linkage or linkage in need of lubrication or adjustment. Hard shifting may also be caused by binding shift rails or forks *inside* the transaxle. Some hard shifting problems are caused by clutch problems.

Sometimes, hard shifting results when the transaxle case and engine are misaligned or when the engine or transaxle mountings are misaligned. Most front-wheel drive vehicles have at least one mount from the top of the engine to the body. This mount very commonly wears out, becomes loose, or even breaks, causing hard shifting.

Hard shifting can be diagnosed easily. If the gearshift lever is hard to move even when the engine is stopped, the linkage is probably the source of the problem. If the gearshift lever moves easily when the engine is stopped but becomes hard to move when the engine is running, the problem may be in the clutch or the transaxle synchronizers.

In many cases, hard shifting can be reduced or corrected by adjusting or lubricating the shift linkage. The shift linkage is a common source of trouble on transaxles, since the linkage must be long enough to connect the gearshift lever with the transaxle case. If internal parts of the shift linkage are bent or sticking, the transaxle must be removed and disassembled to make repairs.

Synchronizer or clutch problems require transaxle removal. If the transaxle or engine is out of alignment, realignment may be possible without removing the transaxle.

Gear Disengagement

Gear disengagement is a condition in which transaxle transmission gears and synchronizers disengage on their own, causing a transaxle to come out of gear. More specifically, the problem may be either gear jumpout or gear

slipout. The two conditions are closely related. With **gear jumpout**, the components are fully engaged, but something happens to force them out of engagement, into Neutral. With **gear slipout**, the gears and synchronizers are never quite fully engaged when they should be. When this happens, gear rotation tends to push the synchronizer outer sleeve and mating gear out of engagement.

Jumpout generally occurs when some outside force overcomes spring pressure in one of the detent holding mechanisms of the shift linkage. Often, there is a problem with the detent mechanism, such as broken springs or worn detent notches. The problem could also be in the shift rails of an internal shift linkage or in the gearshift lever assembly. If the problem is a detent, the driver may make a false assumption and relate that the problem occurs in high gear only. The driver may only notice the problem in high gear because this is the only gear in which he or she is not holding on to the gearshift lever.

There are a number of conditions that can cause gear slipout. The first step in finding the cause of the problem is to determine which gear(s) is slipping out of engagement.

If the transmission slips out of a reduction gear, begin by checking for problems in the linkage. It could be worn or improperly adjusted. There may be interference between the shift linkage and some other part of the vehicle, or the shift linkage may be binding for some other reason, such as from a tight shift lever seal on the transaxle. These actions can limit travel of the shift forks and prevent the synchronizers and mating gears from fully engaging. Linkage interference is often the cause if the problem occurs only when the vehicle is in a gear (high gear included) and accelerated.

If the linkage is all right, check for chipped or broken gear teeth. Defective teeth may be causing the problem (or may be the result of something else that is causing the problem). Check the splines on the synchronizers. Worn or damaged splines on the outer sleeve or inner hub could be causing slipout. Also check the pilot and input shaft bearings and bearing retainer. A worn or damaged pilot bearing or an input shaft bearing or retainer that is broken or loose can cause enough gear movement to push the sleeve and gear apart.

If the transaxle slips out of high gear *only*, begin by checking for loose transaxle case-to-engine bolts, which hold the transaxle case to the engine. Also, check the engine mounts, especially the top mount. Often, a worn top engine mount will not be obvious and will require removal to make sure it is not defective. Another cause is a misaligned transaxle case. Sometimes, the entire engine and transaxle assembly is misaligned. Other causes include worn or binding shift linkage.

At times, jumpout and slipout problems can be corrected without removing the transaxle. Often, external shift linkage problems can be corrected by lubrication or adjustment. Sometimes, however, linkage parts are too worn to be corrected by adjustment and must be replaced. When the problem is caused by worn or damaged internal parts, the transaxle must be removed and disassembled.

Gear Clash

Gear clash is a grinding noise that is heard when a gear is first engaged. For this problem, always check the clutch adjustment and condition before working on the transaxle. A clutch that does not fully disengage is the most common cause of gear clash, especially if the clash occurs in every gear. If the clutch checks out all right, or if the clashing occurs only in one gear, check for worn transaxle synchronizers. In a few cases, loose mounting bolts or misalignment will cause gear clash.

Abnormal Noise

An **abnormal noise** in the manual transaxle is a noise above normal sound level during vehicle operation. Noises that are most noticeable may sound like whining or rumbling and may change from gear to gear, varying directly with the reduction ratio. Low gear, with its higher gear ratio, for instance, is usually noisier than high gear.

Front-wheel drive vehicles normally have higher noise levels than rear-wheel drive vehicles, since the moving parts are mostly concentrated at the front. Be sure to eliminate the engine, clutch, CV axle, and wheel bearings as possible causes of the problem. If the noise occurs in one gear only or in Neutral with the vehicle stopped, you can safely assume that the problem is in one of the gears or synchronizers in the transaxle.

If the transaxle is noisy in every gear, including Neutral, first check for a low oil level. Other defects that could cause noise in every gear (and sometimes Neutral) are worn or damaged transaxle transmission gears. Rumbling noises are often caused by worn or damaged bearings on the input or output shafts or in the differential assembly. Noise in every gear when moving may be caused by a defective speedometer gear.

A clunking or slapping noise heard when the engine is accelerated or decelerated may be caused by excessive backlash in the moving parts, most commonly in the differential unit. This can be due to worn or missing thrust washers, badly worn gears, worn or misaligned bearings, or loose bolts. Be sure to check the clutch, engine mounts, and CV axles before removing the transaxle. Clunking noises are much more likely to be coming from the CV axles than the transaxle.

Correcting most noises requires transaxle removal to gain access to defective gears or bearings. In some cases, such as with loose bolts or misalignment, the problem can be fixed without removing the transaxle.



Warning: Always keep safety uppermost in your mind when checking for transaxle problems. Be cautious around rotating parts when testing the transaxle with the vehicle on a lift. The CV axles and tires rotate at high speeds and can cause severe injury.

Always support the lower control arms so the front wheels are at or near their normal position in relation to the vehicle body. Operation of the CV axles at excessive angles by allowing them to hang will cause severe CV joint damage and possible injury to anyone near the vehicle. When testing a front-wheel drive vehicle on the lift, never exceed 30 mph (48 km/h).

In-Car Manual Transaxle Service

Do not remove the transaxle until you are sure it must be removed. In many cases, the transaxle can be serviced without removing it from the vehicle. For instance, the shift linkage, axle seals, and speedometer gears can be serviced without removing the transaxle.

External shift linkage is one area of the manual transaxle that is vital to proper operation and that can be repaired without transaxle removal. The procedures for adjusting transaxle shift linkage are similar to the procedures for adjusting linkage on rear-wheel drive manual transmissions. The linkage of a front-wheel drive vehicle, however, is usually not contained inside the transaxle in the manner of many rear-wheel drive transmissions, since the transaxle is located well ahead of the passenger compartment.

Many transaxles use cables to connect the shift mechanism of the gearshift lever assembly to the transaxle gears. Most cable adjustment mechanisms are located at the gearshift lever assembly. Adjustments can be made by removing the console or shift boot to reach the adjustment mechanism. If the vehicle uses a shift rod mechanism, the adjustment must usually be made under the vehicle or at the transaxle under the hood.

Manual Transaxle Removal

If the transaxle has internal problems, such as defective gears, bearings, or shafts, it will generally have to come out of the vehicle. Note that in some instances, however, certain internal parts can be serviced with the transaxle in the vehicle by removal of a sheet metal or aluminum access cover.

Most manual transaxles can be removed from underneath the vehicle without removing the engine. A few vehicles are designed so that the transmission and engine must be removed as a unit. On others, under-the-hood clearances are so close that it is easier to remove them this way. In this case, you must have a good engine hoist and know how to use it.

The following *general* procedures explain how to remove a manual transmission from a vehicle. The removal process presented in this chapter assumes the transaxle can be removed without removing the engine. Keep in mind that the removal process is much different from that used on a rear-wheel drive transmission. Note that you

should always refer to the manufacturer's service information for specific procedures.

1. Disconnect the battery negative cable to prevent shorting wires or accidentally operating the starter.
2. While under the hood, remove the upper transaxle case-to-engine bolts, clutch and shift linkages, electrical connectors, and ground straps. In many cases, it will be necessary to install an engine holding fixture to remove the engine weight from the lower engine and transaxle mounts. A typical engine holding fixture is shown in **Figure 11-3**.
3. Raise the vehicle to get enough clearance to remove the transaxle. If you do not have access to a hydraulic lift, use a good hydraulic floor jack and approved jack stands.



Warning: Never support the vehicle with wooden crates or cement blocks. Be sure the vehicle is secure before working underneath it.

4. Check the engine mounts to ensure they are not broken. Broken mounts could be the cause of shifting or clutch problems.
5. Remove the splash shields and any other hardware that will be in the way during CV axle or transaxle removal. Then, remove or disconnect one of the CV axles. In some cases, it is possible to remove the CV axle from the transaxle without removing it completely from the vehicle, as in **Figure 11-4**. Be sure to securely wire the axle in place to prevent damage. CV axle removal is covered in detail in Chapter 15.



Caution: Be sure to remove the CV axles in the proper manner, or the axles or other vehicle parts can be damaged.

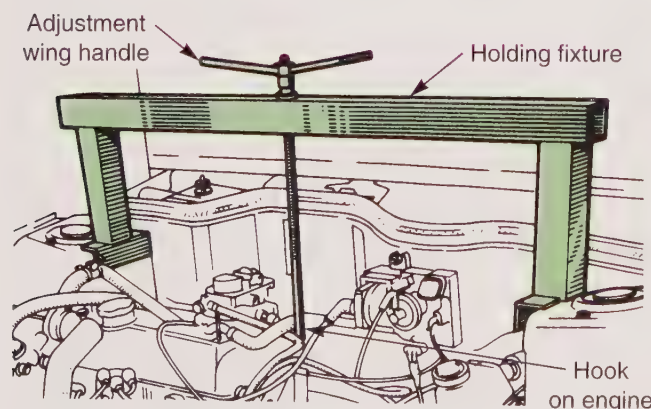


Figure 11-3. This engine holding fixture can be used to remove engine weight from the engine and transaxle mounts. (Chrysler)

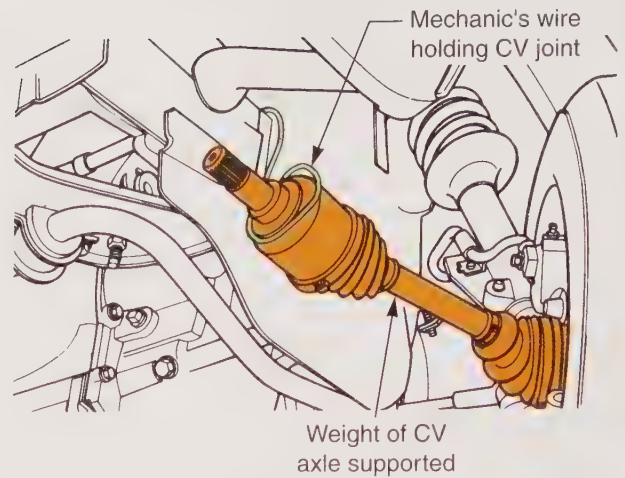


Figure 11-4. The CV axles are usually removed from the vehicle to remove the transaxle. A few can be removed from the transaxle without being disconnected at the wheels, as shown here. The CV axle should be tied to the vehicle body to prevent excessive CV joint angles and damage. (Ford)

6. Once one of the CV axles is removed, allow the transmission oil to drip into a drip pan. Then, remove the other CV axle from the transaxle. Plug the CV axle openings to reduce oil leakage.
7. Remove the speedometer cable assembly.
8. Remove the dust cover in front of the clutch and flywheel. Remove the starter if it is bolted to the transaxle clutch housing.
9. Remove the exhaust pipes if necessary to gain clearance for transaxle removal. On some vehicles, it may also be necessary to unbolt and swing out the front frame extension or engine cradle to remove the transaxle. On other vehicles, some suspension parts must be removed to gain enough clearance to lower the transaxle. Consult the specific service manual to be sure you perform this procedure properly.
10. If an engine holding fixture is not already in place, support the engine with a jack placed under the rear of the engine.
11. Loosen the remaining transaxle case-to-engine bolts.



Warning: Always leave at least two bolts holding the transaxle to the engine until you have a transmission jack under the transaxle. Although most transaxle cases are aluminum, they are heavy. You should always use a transmission jack to support and lower the transaxle.

12. Place the transmission jack under the transaxle and raise it slightly to remove weight from the lower transaxle mounts. See **Figure 11-5**. Then, remove the lower transaxle mounts and any other parts holding the transaxle to the vehicle body.

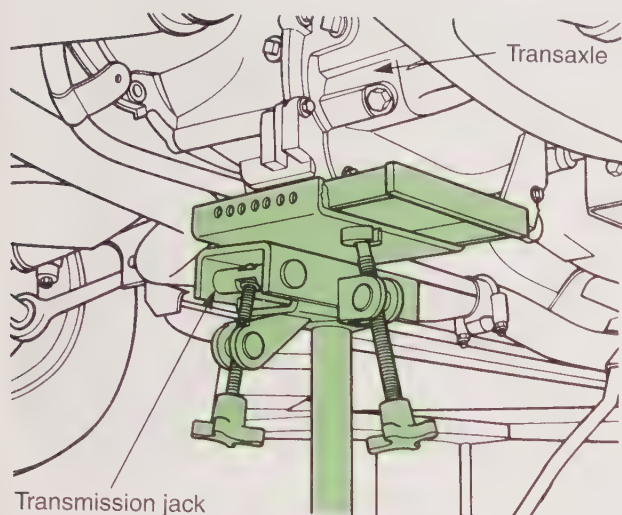


Figure 11-5. A transmission jack must be used to remove the transaxle. Always secure the transaxle to the jack before removing the final transaxle case-to-engine bolts. (Ford)

13. Remove the last bolts holding the transaxle to the engine. Raise or lower the transmission jack until there is no binding between the splines on the transaxle input shaft and the clutch disc.

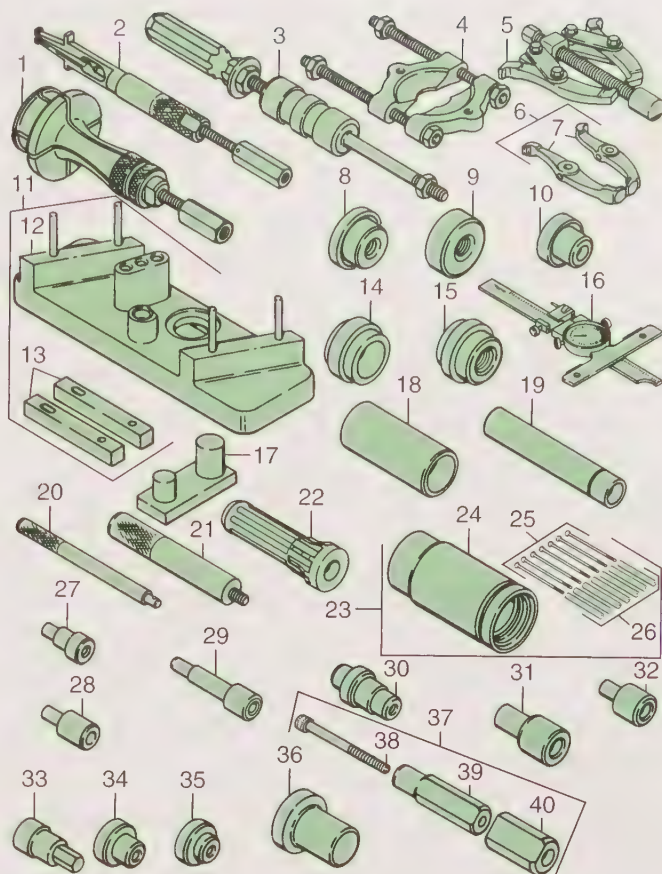


Caution: Do not let the transaxle weight rest on the clutch assembly. This will damage the clutch disc hub and possibly the transaxle input shaft.

14. Slide the transaxle away from the engine until the input shaft clears the clutch disc. Then, lower the transaxle, watching clearances, which are usually close on front-wheel drive vehicles. Also, watch for any component that you may have forgotten to disconnect, especially any electrical connectors, ground wires, or other wiring connected to the transaxle.
15. As soon as the transaxle is clear of the vehicle, lower it to the floor and transport it to the workbench in the lowered position. If the transaxle is very dirty, you may want to remove some of the outside dirt before beginning disassembly.

Manual Transaxle Disassembly

Once the transaxle is removed, it can be disassembled for cleaning, inspection, and repair. The procedure outlined here is general and does not specifically cover any one transaxle. You should always consult the manufacturer's service information for exact disassembly procedures and specifications. In addition, the tools needed for servicing vary with each transaxle. These tools are covered in detail in the service manual. A typical set of special service tools is shown in **Figure 11-6**.



Special Tools Muncie (5-speed) Transaxle

Tool Name	Item Number
Universal driver handle	21
Side bearing puller adapter, differential	34
Bearing remover	5
Bearing remover leg (two)	7
Bearing remover leg set	6
Input/output shaft gears remover	4
Differential inner bearing installer	10
Differential and output shaft bearing cup installer	15
Side bearing puller adapter, differential	35
Slide hammer and adapter set	3
Metric dial depth gage	16
Shim selection set	23
Differential shimming gage	24
Shim selection set spacers (seven)	26
Bolts, M8 x 1.25-6g/length - 160 mm (seven)	25
Seal and race, differential, installer	8
Shift shaft seal installer	22
Input bearing assembly remover/installer/shaft support bearing installer	36
Shift shaft bearing remover	27
Shift rail bushing remover/installer	37
Adapter to drive handle	40
Install/remover adapter	39
Cap screw, 1/4-20 x 2 1/2	38
Reverse shift rail bushing installer	28
Bearing retainer bolt hex socket	33
Clutch shaft inner reverse shift rail bushing remover	2
Clutch shaft inner bushing installer	31
Sliding sleeve bushing remover/installer	29
Clutch shaft upper bushing remover/installer	19
Output shaft bearing cup remover	1
Shift detent lever bushing remover/installer	30
Differential bearing cup remover	9
Input/output shaft remover/installer assembly set	11
Pallet	12
Disassembly adapter (two)	13
Input shaft remover/installer press tube	18
Output shaft remover/installer adapter press tube reducer	14
Input/output shaft bearing remover	17
Shift shaft bearing installer	32
Universal driver handle	20

Figure 11-6. The service tools shown here are used to repair a common make of manual transaxle. The type of tools needed for the job will vary with the type of transaxle. (General Motors)

If possible, mount the transaxle in a holding fixture before beginning disassembly. If a holding fixture is not available, make sure the transaxle is securely mounted on the workbench. One way to secure the transaxle is to tighten one of the projecting parts of the case in a vise, letting the transaxle weight rest on the workbench.

Removing External Components

Start the disassembly by removing the external parts of the transaxle, such as the speedometer driven gear, **Figure 11-7**. If the clutch throwout bearing and clutch fork were removed from the vehicle with the transaxle, remove the throwout bearing from its hub and from the clutch fork; then, remove the clutch fork from its installation. Remove any sheet metal or cast aluminum covers.

Before taking the case apart, shift the transaxle through its gears. This will make it easier to spot any defects in the shift linkage. Then, take the case apart. Many transaxle cases are made in two halves or as a center support with end covers. Remove the through bolts and pry the case halves apart. Sometimes, the case halves can be separated by lightly tapping them with a soft-faced hammer, **Figure 11-8**.

Note that some cases contain ball bearings or tapered roller bearings to support the shafts. The shafts may be held to the bearings with large nuts that resemble rear axle pinion nuts. These nuts must be removed before the case can be removed. Some retaining nuts have left-hand threads. Make sure the bearings are not damaged during disassembly.



Note: As you disassemble the transaxle, carefully note the position of all parts. If necessary, mark mating parts to ensure proper reassembly.

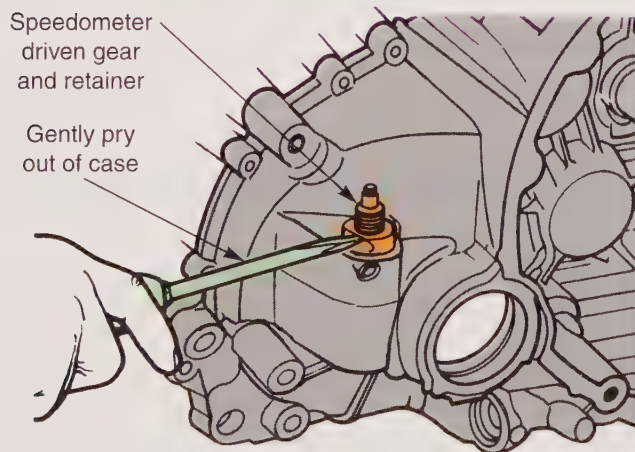


Figure 11-7. Remove all external parts before opening the transaxle case. Many parts are connected to the transaxle shafts and gears, and they will be damaged if not removed beforehand. (Ford)

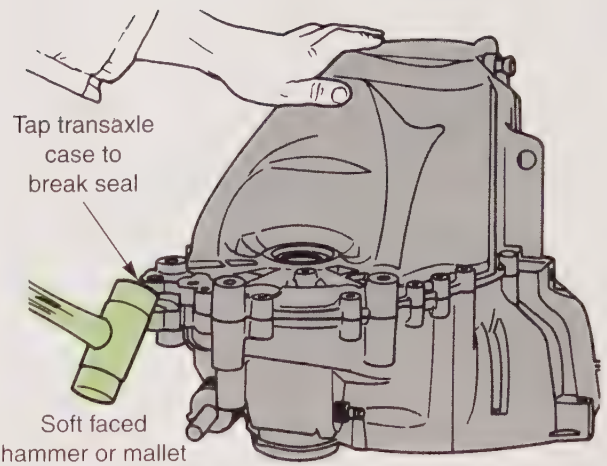


Figure 11-8. Many cases must be split apart by lightly tapping on them after the retaining bolts are removed. Some cases are two-piece units, while others consist of a central support housing with two outer ends. (Ford)

Once the case has been taken apart, the transaxle internals can be inspected for obvious damage. **Figure 11-9** shows a common transaxle gearset as it appears after the upper half of the case has been removed.

Removing Internal Components

Transaxles are often easier to disassemble than manual transmissions, since most moving parts are revealed once the case halves are separated. To begin removing internal parts, you must often remove the snap rings that hold gears to their shafts. The gears can then be removed. In some instances, certain gears are held in place by other types of fasteners. **Figure 11-10** shows the methods necessary to remove gears pressed to a shaft or shafts held in the case by a retaining bolt.

The differential case assembly can also be removed when the transmission internal parts are removed. In some designs, it is removed first; in others, it is removed after the transmission internal parts. **Figure 11-11** through

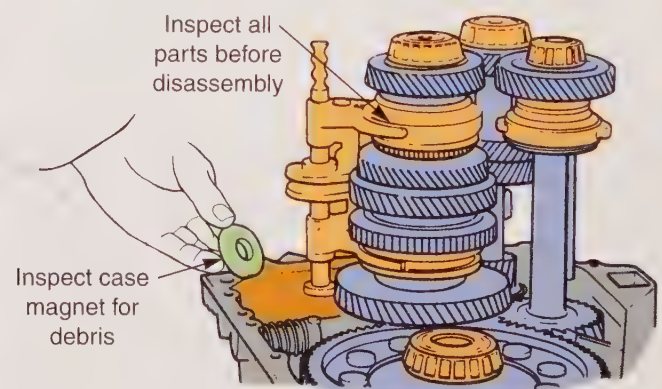


Figure 11-9. After the case is removed, the internal parts can be inspected and removed. All internal parts should be carefully checked for wear and damage before disassembly. (Ford)

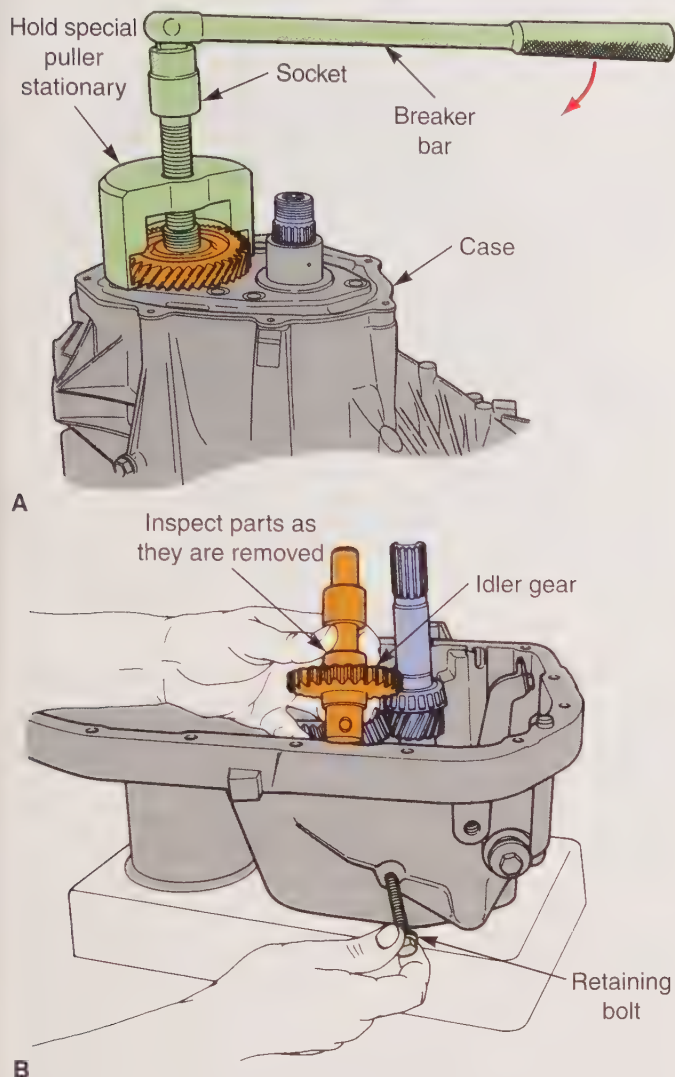


Figure 11-10. Transaxle shafts and gears are installed by many methods. Removal methods vary accordingly. A—Pressed-on gears may be removed with a special puller. B—Removing a special retainer bolt will release a shaft and gear in this transaxle. (General Motors)

Figure 11-13 shows the removal of a differential case assembly from a common make of transaxle.

Most differentials are simple units, using helical gears for the ring and pinion. If the transaxle is used with a longitudinal engine, it probably has a hypoid ring and pinion. This type of differential assembly is overhauled in the same manner as one on a rear-wheel drive vehicle. The differential used with the longitudinal engine is in its own housing, separate from the transmission, and it does not require disassembly unless it, too, is defective. Many hypoid-type differentials used with front-wheel drive vehicles develop case cracks, so they must be checked closely.

Disassembling the Components

The next step in transaxle overhaul is to disassemble the individual components. Disassembly techniques are similar to those used to overhaul manual transmissions.

Some transaxle bearings are pressed onto shafts and must be removed by using a press and the proper adapters, **Figure 11-14**. Since the removal process usually damages the bearings, do not remove the bearings unless they are going to be replaced. Many tapered roller bearings used on transaxles have outer races, or bearing cups, placed in the transaxle case. These also should not be removed unless the bearing is replaced. Always mark the bearing cups if they are removed. This will ensure that they are reinstalled in their original positions, **Figure 11-15**.

Some gears may need to be pressed off their shafts, while other gears are integral with their shaft. Most gears are held onto their shaft by snap rings. Pay particular attention to the synchronizer blocking rings during gear removal to prevent damage to the soft brass. The gears and synchronizers should be laid on the workbench in order of disassembly. See **Figure 11-16**. Careful disassembly of parts makes reassembly easier. Inspect all parts as you disassemble them. This enables you to determine which parts require replacement.

Other parts that require disassembly are the internal shift linkage and any bearings that were not removed in previous steps. Damaged shift forks or shift rails may require further disassembly, **Figure 11-17**.

The differential case assembly should also be disassembled for inspection. If necessary, the differential side bearings can be removed using the proper puller, **Figure 11-18**. Since the removal process usually damages the bearings, they should not be removed unless they are going to be replaced.

Transaxle seals should be removed from their housings once all other parts are removed. Most seals can be pried from their housings with a screwdriver. When removing seals, be careful not to nick or dent any gasket sealing surfaces or seal housings.

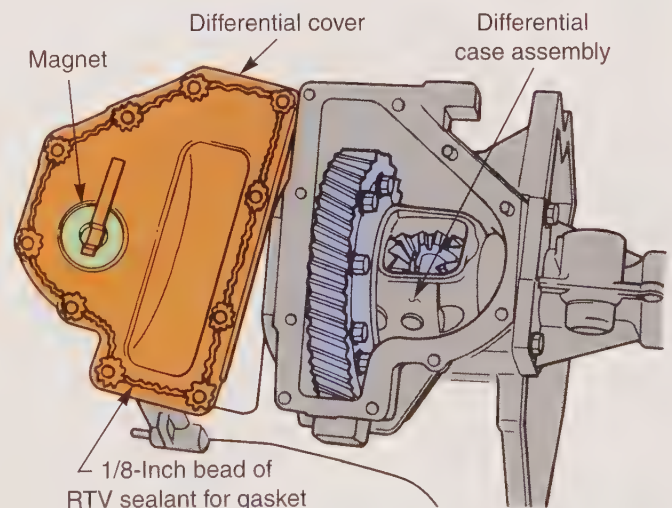
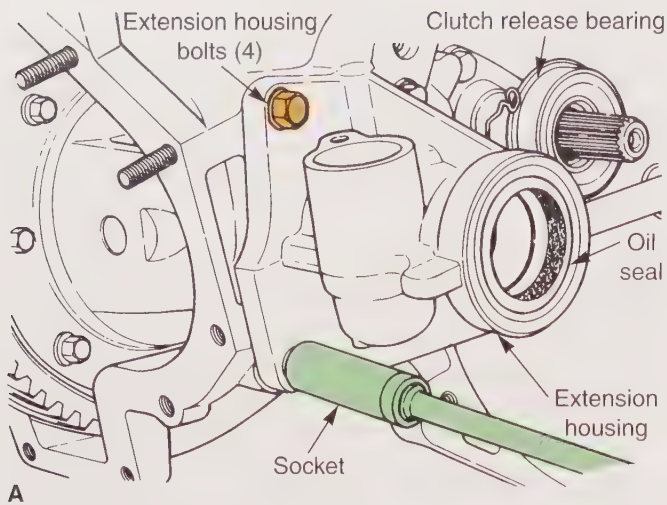
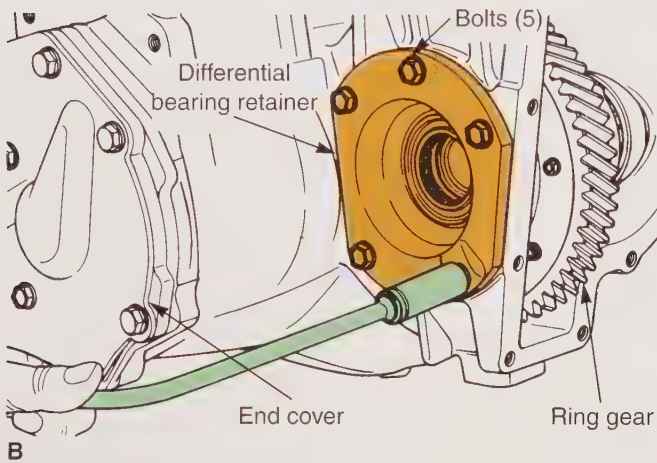


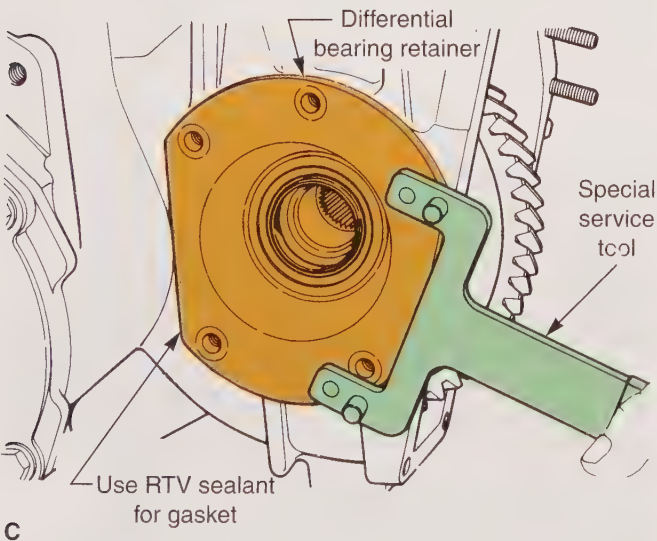
Figure 11-11. The transaxle differential case assembly is often installed under a special cover, as shown here. It must be removed to gain access to this differential unit. The cover contains a magnet to pick up metal particles. (Chrysler)



A



B



C

Figure 11-12. The differential assembly can be removed by following the factory service procedure. A—Removal of a CV axle extension housing. B—After the extension housing is removed, the differential bearing retainer bolts can be accessed. C—With bolts removed, the bearing retainer is then rotated to remove it. (Chrysler)

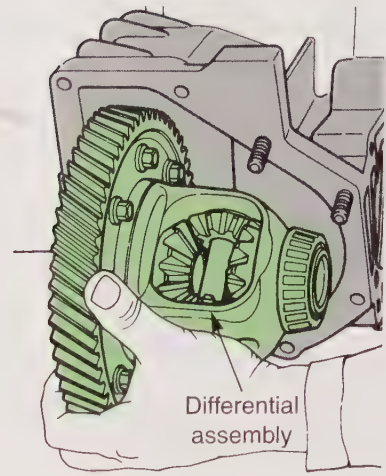


Figure 11-13. After the differential bearing retainer is removed, the differential case assembly is lifted out through the differential cover opening. (Chrysler)

Manual Transaxle Parts Inspection

Almost any transaxle part can wear out or become defective in some way. You should check every part for possible problems. Begin by thoroughly cleaning the transaxle case halves and all internal parts with fresh cleaning solvent. When cleaning the cases, make sure no small parts, such as needle bearings, are lost. If you clean any parts with water, dry them thoroughly with compressed air and coat them with oil.

While inspecting the transaxle, also check related parts that may still be attached to the vehicle. Examples are the external shift linkage, clutch disc and pressure plate assembly, flywheel, crankshaft pilot bearing, and CV axles.

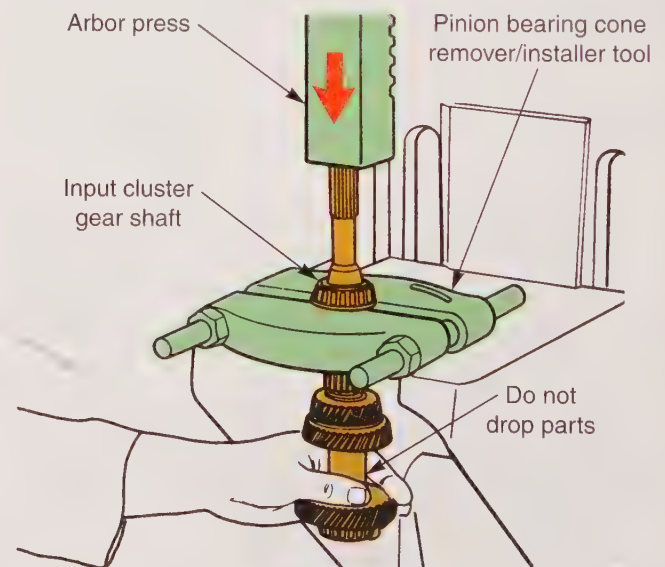


Figure 11-14. Some transaxle bearings are pressed onto the shaft they support. The bearings must be removed with a press, as shown here. (Ford)

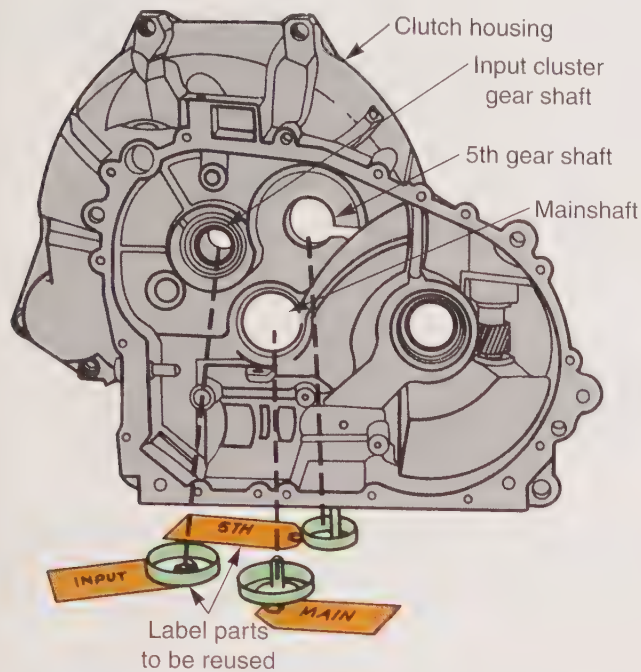


Figure 11-15. Various bearing cups are located in the transaxle case. Do not mix up any bearing cups that are the same size, since bearings and cups have worn in to fit each other. (Ford)

Visual Inspection

Visual inspection can be performed to uncover any obvious damage. Since transaxles have smaller gears and shafts than most manual transmissions found on rear-wheel drive vehicles, they are more likely to become worn or damaged. You should check shaft splines and snap ring grooves carefully, **Figure 11-19**. Any signs of wear on these areas mean the shaft should be replaced.

Check the synchronizers for wear or broken teeth, and check the grooves in the outer sleeves to look for wear caused by contact with the shift fork. Check the gears for worn, cracked, or chipped gear teeth, **Figure 11-20**. If any teeth on a gear are defective, the entire gear should be replaced. Also, inspect the transaxle drive chain for wear.

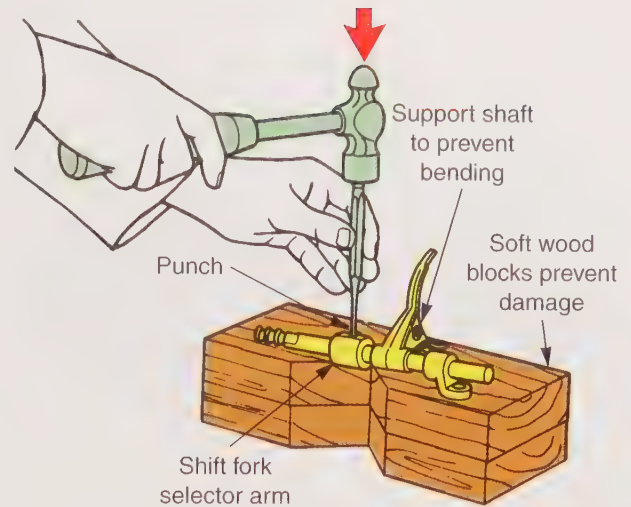


Figure 11-17. Most shift forks are attached to the shift rails with a retaining pin. It is necessary to tap out the pin to disassemble the parts. (Ford)

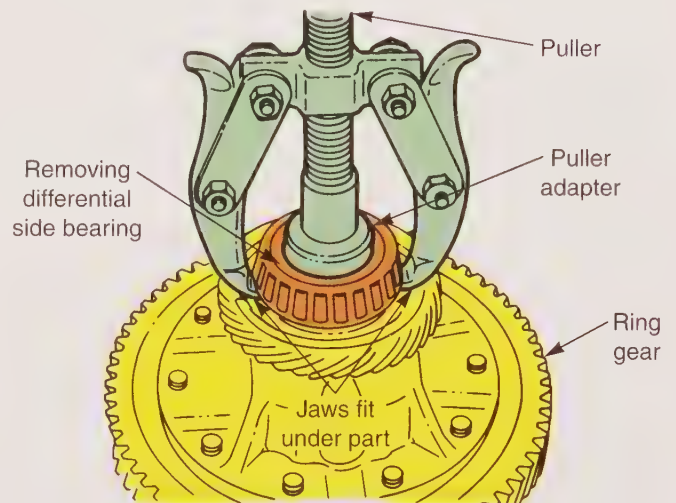


Figure 11-18. The differential side bearings are pressed into place, just as on a rear-wheel drive differential. The bearings must be removed with a puller. Do not remove the bearings unless they are being replaced. (General Motors)

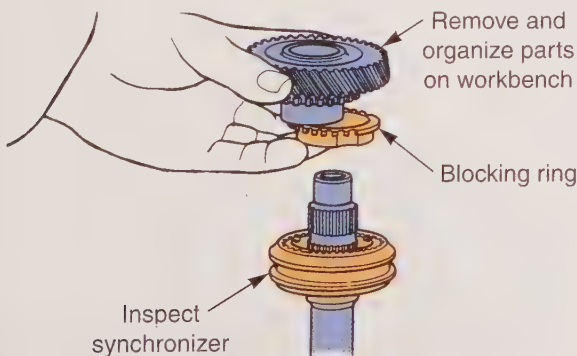


Figure 11-16. Carefully remove the synchronizers and gears from their shafts and keep all parts in order on the workbench. Check parts for wear and damage as you disassemble them. (Ford)

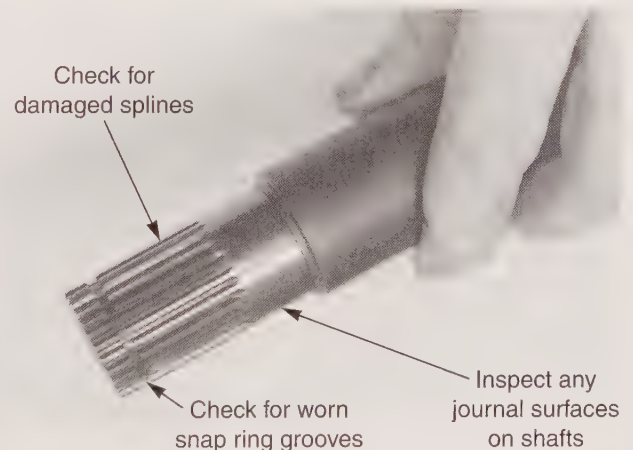


Figure 11-19. Check the transaxle shafts for wear, especially the splines and snap ring grooves.



Figure 11-20. Check gears for damage at the teeth. This gear has both drive and synchronizer teeth. Both sets of teeth should be carefully checked.

Inspect all ball and needle bearings for wear or looseness. The transaxle bushings and thrust washers should also be checked for wear and scoring. Do not forget to check the condition and fit of all bearing surfaces that contact and turn against their supporting shaft. See **Figure 11-21**.

The differential requires inspection when the transaxle is overhauled, unless it is contained in a separate housing. Check the differential gears for wear or damage and the differential case for problems. If necessary, remove the ring gear from the differential case, **Figure 11-22**. Replace any damaged or worn differential parts. Replace seals or gaskets used for separating differential lubricant from transaxle lubricant.

Check the transaxle case and all other stationary parts at this time for cracks and any distortion, which may cause leaks, poor sealing surfaces, or misalignment of the moving parts. Also, check the clutch throwout bearing and any clutch linkage that is attached to the transaxle case.

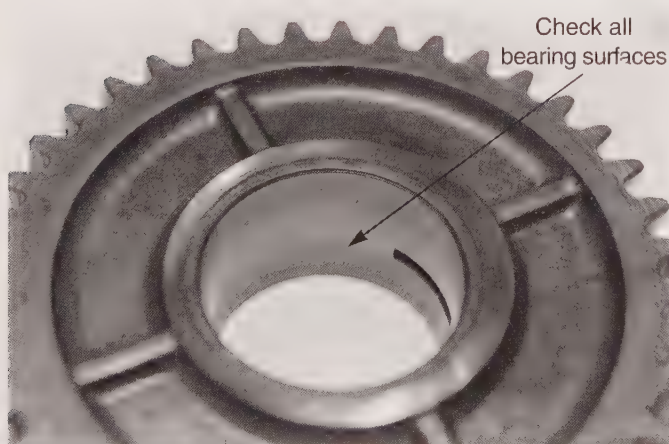


Figure 11-21. Bushing surfaces should be checked for wear. Replace any gear with worn out bushing surfaces, even if the teeth are in good condition.

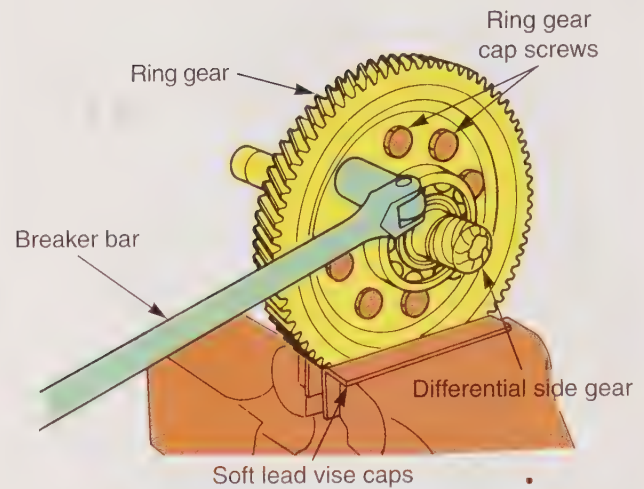


Figure 11-22. The differential case and ring gear can be taken apart by removing the cap screws. This should not be done unless one of the components must be replaced.

Measurement Inspection

Many transaxles have parts that should be checked with measuring instruments. Feeler gauges, micrometers, sliding calipers, and dial indicators are often necessary to identify defective parts that would otherwise be unnoticed. Use of these instruments help ensure a good repair job. Measurement instruments are covered in Chapter 3. Measurement checks performed are similar, in many cases, to those for overhauling manual transmissions and differential assemblies of rear-wheel drive vehicles. Consult Chapter 9 and Chapter 17 for typical examples.

Manual Transaxle Assembly

This section covers the *general* details of manual transaxle reassembly. Before beginning reassembly, make sure you have the correct replacement parts by comparing them to the old parts. Always use new gaskets and seals and lubricate all the moving parts before reassembling them.

Install the differential case assembly—before or after assembling the transaxle transmission, as required. To put the transmission back together, reassemble all the transmission gears, synchronizers, and shafts. Once assembled, ensure that synchronizers work properly. Reassemble the shift forks and shift rails and install them on the input and output shaft gear assemblies. Then, place the entire assembly in position in the case, **Figure 11-23**.

Note that some gear assembly parts may need to be installed individually into the case, as shown in **Figure 11-24**. Some shift forks, for example, are installed after the gears are in place. In this instance, be sure to properly align them before tightening the set screw, **Figure 11-25**.

Reinstall all washers in the position and direction shown in the factory service manual. Some washers used

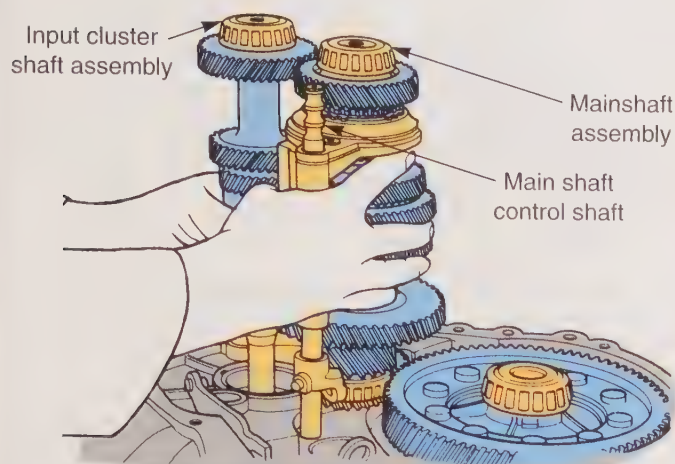


Figure 11-23. Shift forks and rails and input and output shaft gear assemblies are lowered into position as a unit. Be sure to align all parts before installation. (Ford)

with manual transaxles function as oil pumps, delivering oil to the shafts as they flex during shifts. To function properly, these washers must be installed as specified.

In many transaxles, shaft endplay must be checked before the case halves are reassembled. One method of checking endplay involves using a dial indicator, as on a rear-wheel drive transmission. **Figure 11-26** shows another method of checking endplay that involves the use of measuring tools. Adjusting the endplay can be done with adjusting nuts or by installing thrust washers of different thicknesses.

Once all internal parts have been installed, the case halves can be reassembled. Always use the proper kind of sealer or gasket. Do not substitute gasket material for RTV sealer or replace a gasket with a thicker one. Doing so changes the endplay adjustments on the transaxle shafts, and it affects the preload on the tapered roller bearings. **Figure 11-27** shows assembly of two case halves. After tightening the case halves, make sure the transaxle shafts turn properly. Check shaft endplay once the transaxle is reassembled.

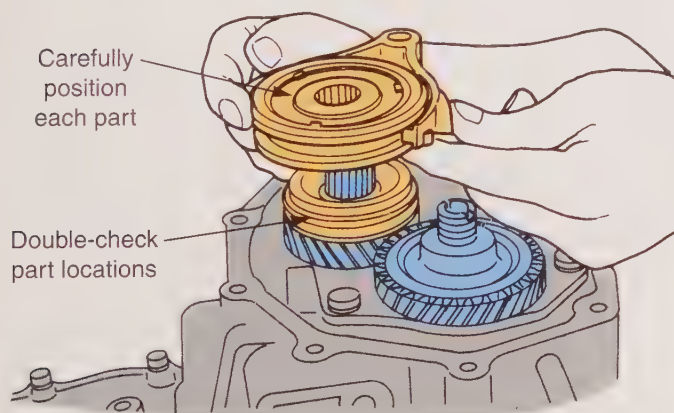


Figure 11-24. Some transaxle shaft components must be reassembled with the shaft installed in the case. You should always recheck part positions before completing reassembly.

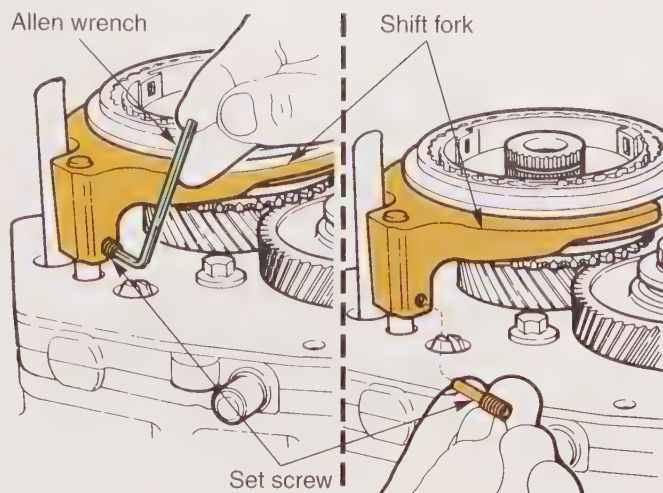


Figure 11-25. The shift forks must be carefully reinstalled to prevent shifting difficulties. It is possible to inadvertently install a shift fork upside down. Consult the service manual if you have any doubts.

If the transaxle uses a separate housing for the internal shift linkage, install it now. **Figure 11-28** shows a typical housing. Be careful to align the shift levers and forks before tightening the bolts. Then, check that the linkage operates properly.

Install the input shaft, if it was not already installed, and install its bearing housing assembly. Also, install and tighten any outer housings, such as the extension housings sometimes used to hold the seals at the CV axles, **Figure 11-29**.

Make sure the transaxle input and output shafts turn without binding. If the shafts do not turn freely, you must find the problem and correct it.



Caution: Do not install a transaxle with binding shafts without correcting the problem. The transaxle will be damaged within the first few minutes of operation.

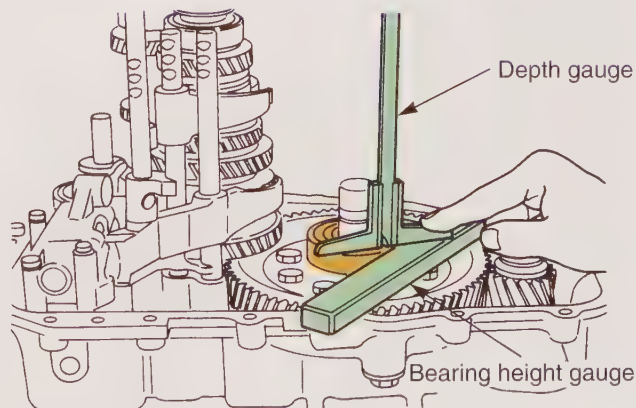


Figure 11-26. Endplay and other adjustments are critical on manual transaxles. Always take measurements according to the directions given in the service manual and correct conditions that are not to specification.

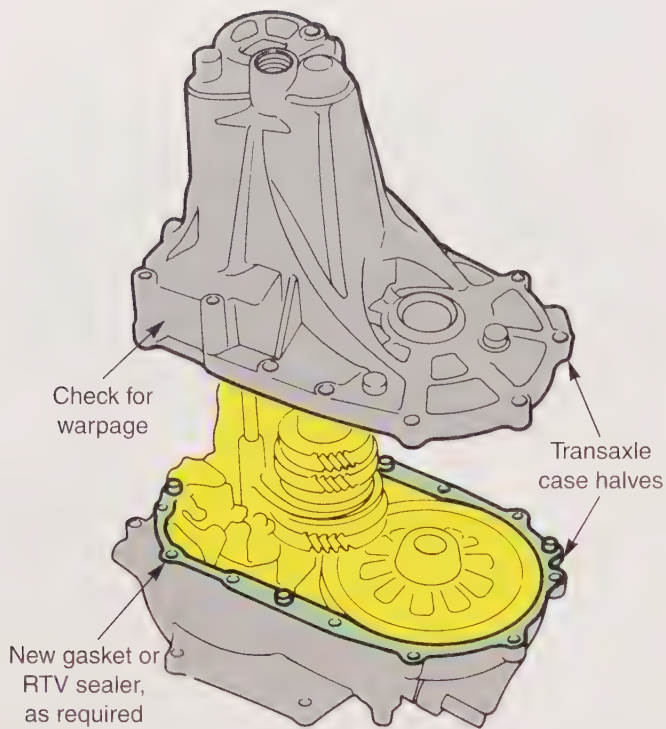


Figure 11-27. The case can be reassembled after all internal parts have been replaced. Use the correct kind of gasket or sealer on the case sealing surfaces to prevent leaks and incorrect bearing preloads. Remove all old gasket material from sealing surfaces before installing new material. (Honda)

Reinstall any external case components, including electrical connectors and linkage. Install the clutch throwout bearing and clutch fork, if they were removed from their installation.

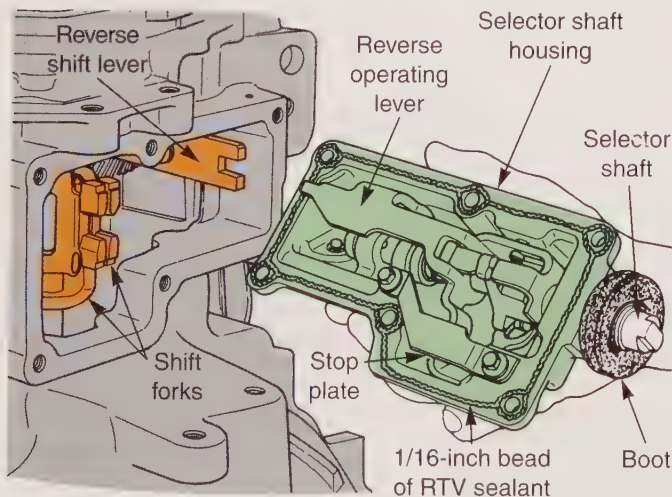


Figure 11-28. A housing for the shift linkage, if used, should be installed carefully, so that the parts line up correctly. If the parts are installed incorrectly, the transaxle gears could be damaged. (Chrysler)

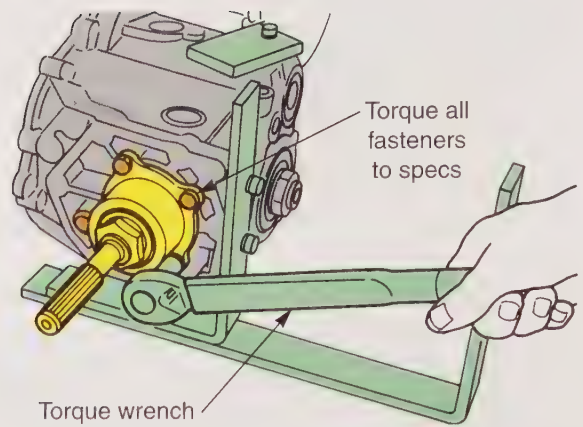


Figure 11-29. Install all extension housings with the proper gaskets or sealer, and torque them to specifications.

Manual Transaxle Installation

The transaxle installation procedure is the reverse of removal. If the installation is performed properly, the transaxle should be easily reattached to the engine and vehicle. The following general procedures detail how to install a manual transaxle in a vehicle. Note that you should always refer to the manufacturer's service manual for specific procedures.

1. Begin by raising the transaxle with the transmission jack. When the transaxle is at the proper height, slide it into engagement with the throwout bearing, clutch disc hub, and crankshaft pilot bushing. If the clutch has been disturbed, you may need a clutch pilot shaft to align the clutch disc. (This was covered in Chapter 7.) If necessary, turn the engine crankshaft to help the input shaft engage the clutch. It may be necessary to remove an access cover to reach the front crankshaft pulley.

As the input shaft passes through the clutch disc hub into engagement with the pilot bushing, the transaxle clutch housing should fit closely onto the engine. Any alignment dowels should smoothly engage their matching holes.



Caution: Do not try to pull a binding transaxle into engagement with the engine by tightening the bolts. This will cause damage to the clutch disc and input shaft, and could possibly break the aluminum transaxle case.

2. Install the transaxle case-to-engine bolts. Make sure the engine and transaxle are properly aligned when all of the bolts are tight. There should be no gaps between any of the mating surfaces. As you tighten, check that no wires, brackets, or hoses are caught between the engine and transaxle.
3. Install and tighten the engine mounts and other fasteners holding the transaxle to the vehicle frame.

4. Install the starter, if it was removed, and the dust cover. Install the speedometer cable assembly, and install the exhaust pipes, if they were removed.
5. Install the CV axles, making sure to match up the alignment marks made during removal. If the CV axles are held in the transaxle with retaining clips, replace the clips with new ones to ensure the axle does not pop out when the vehicle suspension moves. Do not stretch the clips in the attempt to ensure that they hold, since this will make the CV axle difficult to remove the next time it needs service.
6. Install any other frame and body parts that were removed for clearance.
7. Lower the vehicle and reconnect the transaxle shift and clutch linkages, electrical connectors, and any other components that can be reached from under the hood. Make sure you reinstall any ground wires, since they are critical to the proper operation of the vehicle electrical system. Remove the engine holding fixture, if used. Install the battery negative cable last.
8. Make preliminary shift linkage adjustments, if necessary. The clutch linkage may also require adjustment.
9. Fill the transaxle with the proper type of lubricant. If the unit has a separate reservoir for differential lubricant, refill it also.
10. After everything has been reconnected, operate the clutch pedal to ensure that the clutch engages and disengages properly. Also, move the gearshift lever to check operation of the shift linkage. Then, start the engine and road test the vehicle. Make any linkage adjustments as needed and recheck the transaxle fluid level(s).

Summary

Manual transaxle repair is similar to rear-wheel drive manual transmission repair. Since transaxles have mechanical parts, most will eventually wear out. In many cases, the transaxle will develop problems prematurely because of abuse or neglect. Most manual transaxle problems are easy to find if logical troubleshooting procedures are followed. The technician must carefully analyze the symptoms to find the exact problem.

Safety should always come first when working on the vehicle. Support the front suspension when driving the vehicle on a lift, so that the CV axles are not damaged. When road testing, always obey traffic laws and try to use roads that are not congested.

Some transaxle parts can be replaced without removing the transaxle from the vehicle. Before beginning transaxle removal, disconnect the battery negative cable. When removing the CV axles, be careful not to damage them.

Once the transaxle is removed from the vehicle, it should be installed securely on a clean workbench. The external parts should be removed before the case halves or end covers are removed. Once the case halves are removed, the gears and shift linkages can be disassembled. The differential assembly should also be disassembled for inspection.

Inspect all parts for wear and damage. Check the shafts, gears, and bearings. Any defective parts should be replaced. Reassemble the transaxle carefully, following all manufacturers' instructions. If the transaxle gears bind or do not shift easily after reassembly, find and correct the problem. Do not expect binding parts to wear in!

Reinstall the transaxle carefully. Make sure the CV axles are carefully installed to prevent damage. Refill the unit with fluid and adjust the clutch and shift linkages before test-driving the vehicle.

Review Questions—Chapter 11

Answer the following questions using the information provided in this chapter.

1. You should always begin diagnosing manual transaxle problems by _____.
(A) checking the level of the lubricant
(B) adjusting the shift linkage
(C) test-driving the vehicle
(D) finding out why the vehicle was brought in for service
2. What are two relatively minor procedures that solve many manual transaxle problems?
3. Before assuming a transaxle is leaking lubricant, what should you consider?
4. _____ occurs when some outside force overcomes spring pressure in one of the detent holding mechanisms of the shift linkage.
5. What are some conditions that can cause gear slipout?
6. Which of the following would be the *least* likely cause of transaxle gear clash?
(A) Misadjusted clutch.
(B) Worn shift linkage.
(C) Low lubricant level.
(D) Damaged synchronizers.
7. A defective _____ gear may cause noise in every gear when the vehicle is moving.
8. In your own words, explain a general procedure for removing a transaxle.
9. Why must you not let the weight of a manual transaxle rest on the clutch assembly?

10. Since transaxles have _____ gears and shafts than most manual transmissions found on rear-wheel drive vehicles, they are more likely to become worn or damaged.
- (A) smaller
 - (B) larger
 - (C) more
 - (D) less

ASE-Type Questions—Chapter 11

1. Each of the following statements about transaxle problems is true *except*:
 - (A) downshifting at high speeds can damage the synchronizers.
 - (B) high fluid level will reduce part wear.
 - (C) water in the lubricating oil will cause gear pitting.
 - (D) wear of moving transaxle parts can be attributed to high mileage.
2. A front-wheel drive vehicle is noisy in first gear only. Technician A says that the first thing to check is the clutch adjustment. Technician B says that the first thing to check is the condition of the vehicle tires. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
3. A vehicle with a manual transaxle is experiencing hard shifting. Technician A says to check for bent or worn shift linkage. Technician B says to check for linkage in need of lubrication or adjustment. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
4. A driver complains of a manual transaxle coming out of gear. Technician A says a detent mechanism may be faulty. Technician B says to check the shift linkage adjustment. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
5. A car with a manual transaxle is experiencing gear clash. Technician A says to check the synchronizers first. Technician B says to check the clutch adjustment first. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
6. A vehicle with a manual transaxle has a no-drive condition. The engine continues to run when the clutch is released (up position). Technician A says that the no-drive condition could be caused by locked transaxle gears. Technician B says that the no-drive condition could be caused by stripped transaxle gears. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
7. Each of the following service operations can be performed while the transaxle is installed in the vehicle *except*:
 - (A) clutch replacement.
 - (B) clutch adjustment.
 - (C) axle seal replacement.
 - (D) shift linkage replacement.
8. Technician A says that some internal transaxle parts can be serviced by removing an access cover. Technician B says that it is usually easier to remove the engine when the transaxle must be removed. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
9. Technician A says that engine and transaxle misalignment can cause hard shifting. Technician B says that broken engine or transaxle mounts can cause gear slipout. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

10. Transaxle gears may be held to their shaft by each of the following except:
 - (A) snap rings.
 - (B) integral construction.
 - (C) a press fit.
 - (D) case-hardened bolts.
11. Synchronizer blocking rings should be handled carefully, since they are made of _____.
 - (A) plastic
 - (B) brass
 - (C) aluminum
 - (D) cast iron
12. A transaxle case is to be reassembled. Technician A says that you must not replace RTV sealer with a thick gasket on the transaxle case. Technician B says that you can use a thicker gasket than recommended to help ensure the case does not leak. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
13. Which of the following would be the *least* likely cause of transaxle gear clash?
 - (A) Misadjusted clutch.
 - (B) Worn shift linkage.
 - (C) Low lubricant level.
 - (D) Damaged synchronizers.
14. Technician A says that the CV axles should be allowed to hang from the transaxle so that they may be easily removed. Technician B says that the engine should be supported by a special fixture before the engine and transaxle mounts are loosened. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
15. If the transaxle differential assembly is separate from the transmission assembly, it should be disassembled _____.
 - (A) whenever the transaxle is removed from the vehicle
 - (B) when the transaxle is disassembled
 - (C) only if the technician suspects that it is defective
 - (D) only if it is leaking lubricant
16. A reassembled transaxle has improper endplay. Technician A says that the endplay is measured with dial indicators and special measuring tools. Technician B says that the endplay is adjusted by selective thickness shims or by turning adjusting nuts. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
17. Each of the following statements about manual transaxle shift linkages is true *except*:
 - (A) some foreign vehicles have column-mounted gearshift levers.
 - (B) shift linkage may be cable operated.
 - (C) linkage adjustment mechanisms are often found in the gearshift lever assembly.
 - (D) shift linkage rods or cables are longer than those on rear-wheel drive transmissions.



Shift forks move transmission gears or synchronizers on their shaft for gear engagement. (Ford)



Chapter 12

Drive Shaft Assembly Construction and Operation

After studying this chapter, you will be able to:

- ☐ Explain the purpose of a drive shaft assembly.
- ☐ List the major parts of a typical drive shaft assembly.
- ☐ Explain the function and operation of a slip yoke.
- ☐ Explain the function and operation of a universal joint.
- ☐ Name and describe different types of universal joints.
- ☐ Discuss Hotchkiss drive and torque-tube drive.
- ☐ Describe the function of a center support bearing in a two-piece drive shaft.
- ☐ Briefly explain the concept of drive shaft assembly angles.

Technical Terms

Cross-and-roller U-joint

Cardan U-joint

Constant-velocity U-joint

Double Cardan U-joint

Ball-and-trunnion U-joint

Rzeppa joint

Tripod joint

Differential pinion yoke

Differential pinion flange

Hotchkiss drive

Salsbury drive

Torque-tube drive

Two-piece drive shaft

Axial centerline

Rotational axis

Perfect alignment

Drive shaft assembly angle

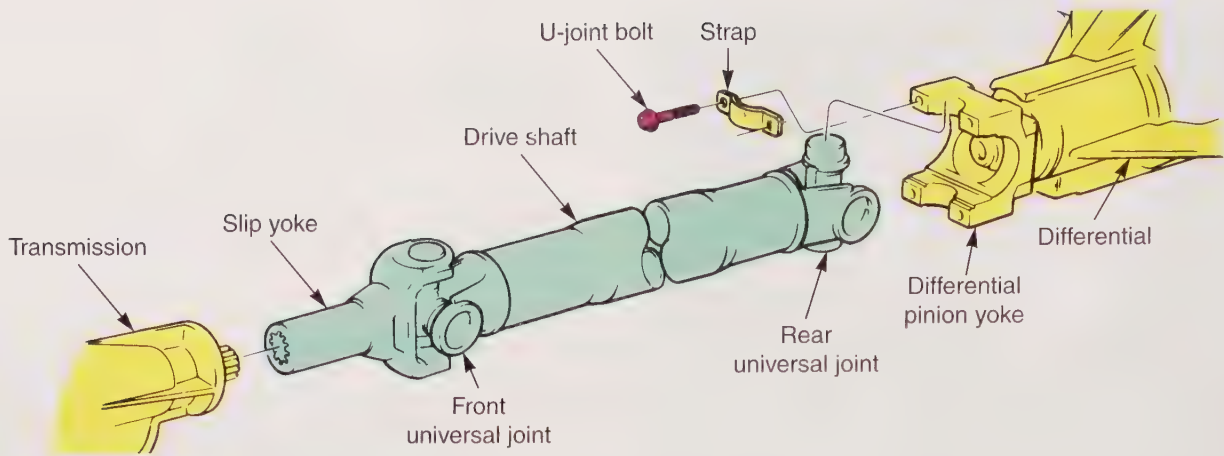


Figure 12-1. Typical drive shaft assembly used on a vehicle with rear-wheel drive. The drive shaft, universal joints, and slip yoke are all part of the drive shaft assembly. The transmission output shaft and differential pinion yoke are also shown. These are the front and rear attaching points for the drive shaft. Note that the shaft is hollow to reduce weight and lessen vibration problems. (General Motors)

Introduction

The drive shaft assembly, or driveline, on rear-wheel drive vehicles transfers power between the transmission and the rear axle assembly. Power transfer occurs while the rear axle assembly moves up and down as the vehicle moves over the road surface. The drive shaft assembly must transfer power smoothly and be strong enough to absorb the shock of rapid power and speed changes.

This chapter discusses the fundamental principles of the drive shaft assembly. The principles discussed here will be of use when servicing the drive shaft assembly.

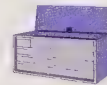
Drive Shaft Assembly

The drive shaft assembly consists of a slip yoke, front universal joint, drive shaft, and rear universal joint, **Figure 12-1**. The slip yoke connects to the transmission output shaft, and the rear universal joint connects to the differential through the differential pinion yoke or

flange. See the exploded view in **Figure 12-2**. The drive shaft contains balance weights to reduce vibration.

Drive shafts come in many sizes and length varies between vehicles. Vehicles of the same model may have different length drive shafts because various transmission sizes are used. Drive shaft length is measured from the center of each yoke hole on the drive shaft ends, **Figure 12-3**.

On a late-model vehicle, both front and rear axles are designed to move to keep the vehicle chassis level with the road surface, providing a smooth ride. On a rear-wheel drive vehicle, the entire rear axle housing and both rear wheels move up and down in relation to the chassis. The rear axle assembly connects to the chassis by a suspension system that allows considerable movement. The assembly moves a great distance as the vehicle travels over bumps and potholes.



Note: Differential assemblies on vehicles with independent rear suspensions are often attached to the vehicle body and do not move in relation to the body.

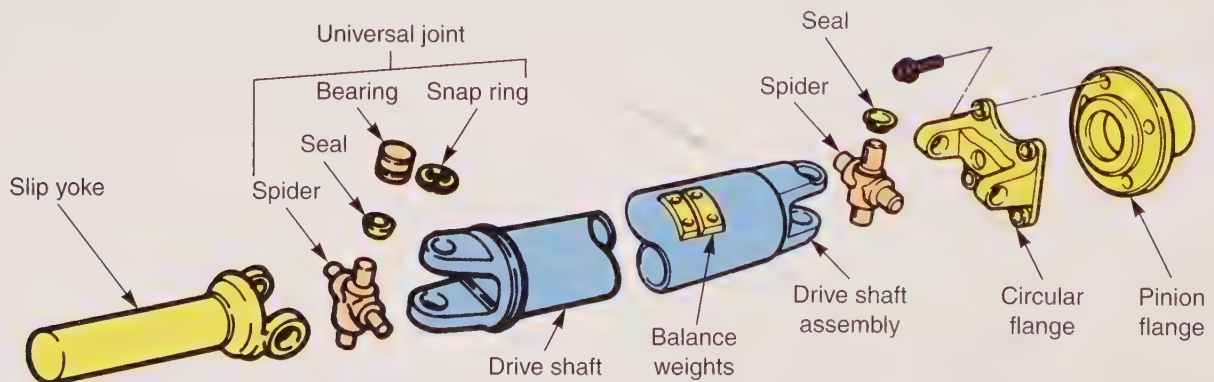


Figure 12-2. Exploded view shows parts of the drive shaft assembly and the differential pinion yoke. (Ford)

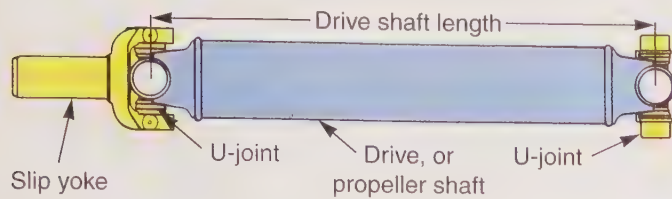


Figure 12-3. Drive shaft length is measured from the center of the front U-joint to the center of the rear U-joint. The drive shaft must be the proper length, or it will not work as it should. A short drive shaft could fall out when the vehicle hits a pothole and the rear axle assembly drops. An overly long shaft will bind when the rear axle assembly rises as the vehicle goes over a bump. (General Motors)

The drive shaft assembly transfers power from the transmission to the rear axle assembly. It must transfer this power as the rear axle assembly moves up and down, which changes the distance between the transmission and the assembly. The effective length of the drive shaft assembly must change to compensate for movement of the rear axle assembly. Since the transmission is solidly attached to the frame of the vehicle, the drive shaft assembly must be able to flex or bend as the rear axle assembly moves. A simple drive shaft, by itself, would break. To provide flexibility, flexible joints are used.

The power flow through the drive shaft assembly begins by entering the slip yoke from the transmission. From the slip yoke, the power flows into the front universal joint and, then, into the drive shaft. Power flows from the drive shaft into the rear universal joint. From the rear universal joint, power flows into the rear axle assembly.

Drive Shaft

The drive shaft, or propeller shaft, is the central part of the drive shaft assembly. The universal joints and other parts are attached to it. The drive shaft consists of a steel tube with yokes welded to or pressed on each end. The shaft has no moving parts. Sometimes, a two-piece drive shaft is used (explained in greater detail later in this chapter).

The drive shaft yokes are the mounting points for the universal joints. The shaft is balanced when it is manufactured. In many cases, balance weights are welded to the shaft. Shafts used on some trucks and a few large cars have heavy, vibration-damping rings attached to them.

Slip Yoke

As the rear axle assembly moves up and down as the vehicle goes over bumps, the effective distance between the transmission and rear axle assembly varies. To allow the drive shaft to adjust to these changes in length, a slip yoke is used where the drive shaft assembly enters the rear of the transmission.

The slip yoke is a steel tube with a yoke at one end. The yoke attaches to the front universal joint. The internal

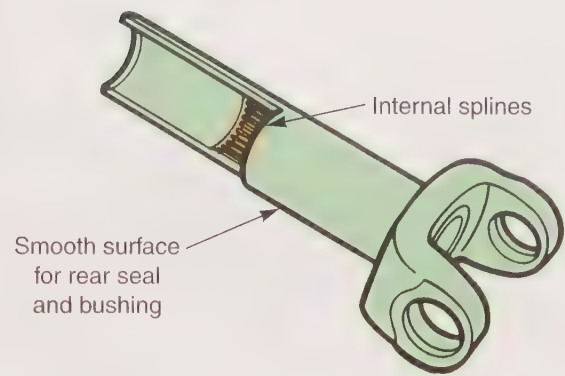


Figure 12-4. The slip yoke is designed to compensate for changes required in drive shaft assembly length. It is made of hardened steel. One end of the yoke has internal splines that form a close fit with splines on the transmission output shaft. The outer surface is smooth to closely mate with the transmission extension bushing. The other end has a yoke, which accepts the front universal joint. (Ford)

part of the tube is splined to match the external splines on the transmission output shaft. The outside diameter of the tube is machined smooth, **Figure 12-4**. It forms a close fit with the transmission extension bushing and rear seal. **Figure 12-5** shows a high inertia damper, which is a weight incorporated into some slip yokes to absorb vibration.

The relationship of the slip yoke to the transmission output shaft and extension housing is shown in **Figure 12-6**. In operation, the slip yoke slides on the transmission output shaft whenever the rear axle assembly moves and changes the effective distance between itself and the transmission. The action of the slip yoke causes the effective length of the drive shaft assembly to change as necessary.

Universal Joints

Most rear-wheel drive vehicles use a swivel connection, or coupling, called a universal joint, or U-joint. Universal joints allow the drive shaft assembly to transmit power smoothly and constantly even though the rear wheels and axle are moving up and down over bumps and dips. Manufacturers use several kinds of universal joints.

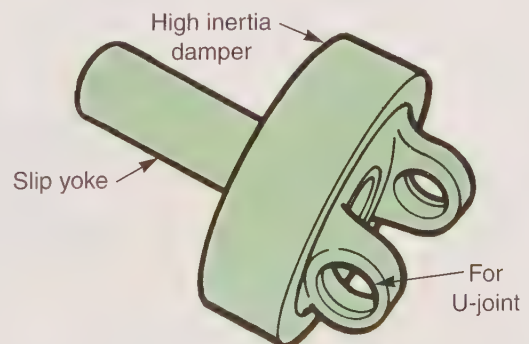


Figure 12-5. This slip yoke has a high inertia damper, made up of a heavy weight, to absorb vibration. (Ford)

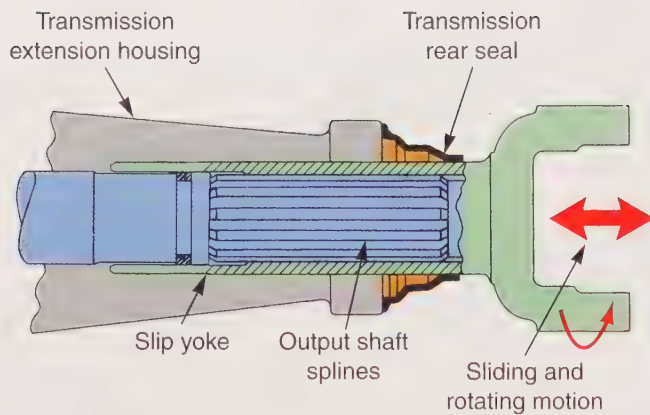


Figure 12-6. Study the cutaway to see how a slip yoke installs into the rear of a transmission. Note that splines are splash lubricated with oil from the transmission. The rear seal prevents transmission fluid leakage past the bushing (not shown) and slip yoke. (Ford)

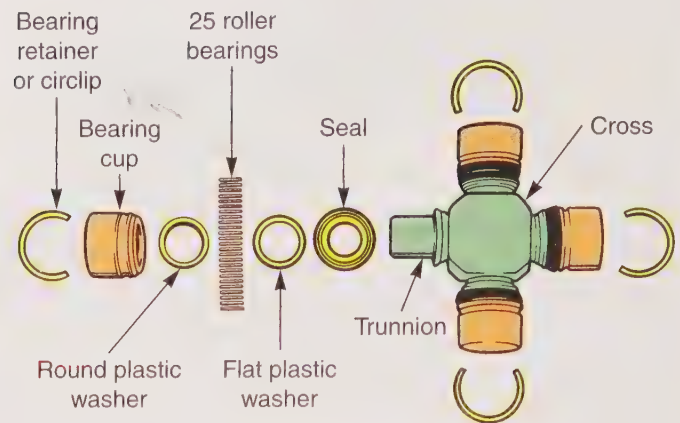


Figure 12-8. Exploded view of a cross-and-roller type universal joint. Bearing cups are retained in their yokes by clips in this installation. Needle bearings and spacers are lubricated by heavy grease. The seal keeps lubricant in and keeps water and dirt out. (General Motors)

Cross-and-roller U-joints

Most rear-wheel drive vehicles use the **cross-and-roller U-joint**, which consists of a center cross (or spider) and four cups (or caps) containing needle bearings. The cups are machined to fit into the drive shaft yokes, the slip yoke, and the differential pinion yoke, **Figure 12-7**. The needle bearings allow the yokes to swivel on the cross ends with minimal friction. This kind of joint is sometimes called a **Cardan U-joint** or a **conventional U-joint**.

Figure 12-8 is an exploded view of a typical cross-and-roller U-joint. The cross ends are called **trunnions**. Since the needle bearings ride on the trunnions, the trunnion surfaces are machined to a smooth finish.

A hole in each trunnion leads to the center of the cross, **Figure 12-9**. A grease fitting often connects to the center of the cross. Grease, injected through the fitting, flows through the holes in the trunnions to each needle bearing. Some universal joints are sealed at the factory and cannot be greased unless they are disassembled.

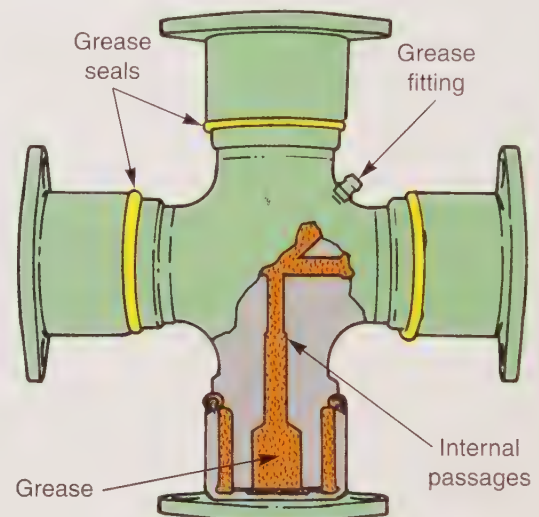


Figure 12-9. Internal passageways in this cross-and-roller universal joint act as a grease reservoir. They allow all the cups to be greased from a single grease fitting. Grease travels from the fitting, to each cup, and then to the needle bearings. (Chrysler)

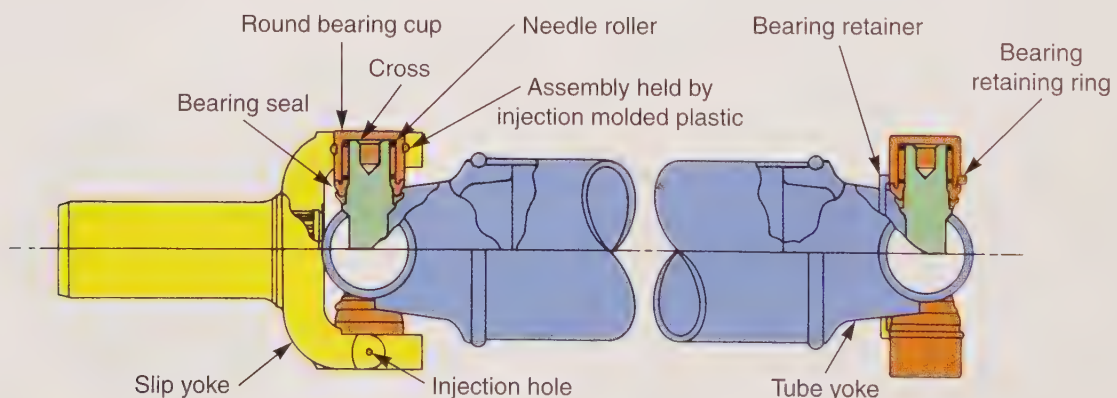


Figure 12-7. Study the cutaways of front and rear universal joints. Notice how the bearing cups and rollers relate to cross and yokes. In this particular installation, the front cups are held in the yokes with injected plastic. This is a common retaining method on many vehicles. To remove the U-joint, the plastic is heated, and the cup is pressed out of the yoke. (General Motors)

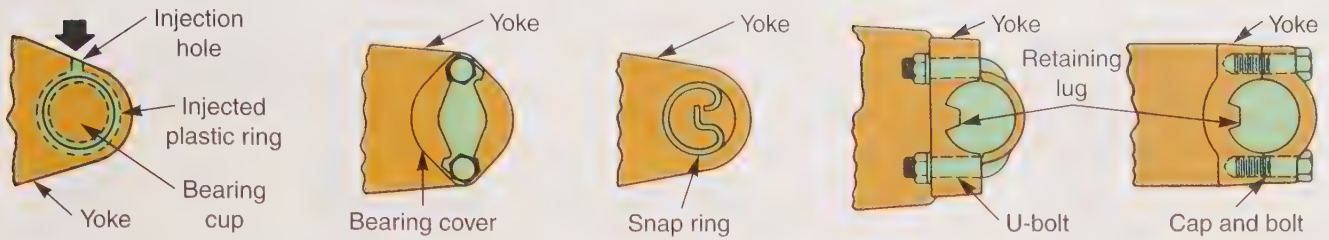


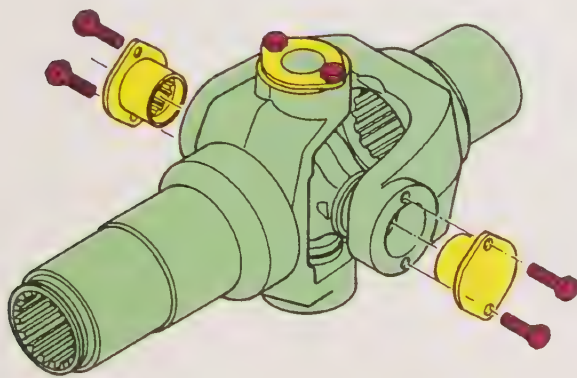
Figure 12-10. Different ways that a bearing cup can be retained are shown here. Injected plastic and clips or snap rings are the most common cup retainers used on automobiles. The retaining lugs shown (far right) are used to align the bearing cups in relation to the pinion flange. Note that bolted cups are found on truck universal joints. (Dana)

The cups may be held in the yokes by retainer snap rings or clips, U-bolts, bolted straps, or bolted covers. Some vehicles use injected plastic to hold cups in place. Some of the different retaining methods for automobiles and light trucks are shown in **Figure 12-10**. Larger vehicles may use the more complex U-joints shown in **Figure 12-11**.

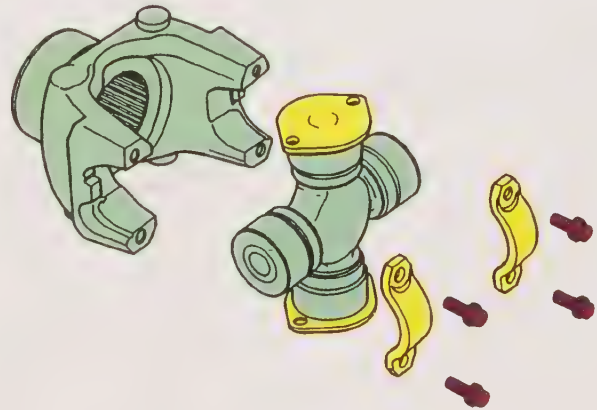
The ends of the cups contain seals that keep the grease in place and prevent the entry of water and dirt. **Figure 12-12** is a sectional view of a typical cup seal.

The action of the universal joint during vehicle operation is a two-way motion. The universal joint rotates with its driving shaft. It also swivels to compensate for changes in drive shaft assembly angles. (Drive shaft assembly angles are discussed later in this chapter.)

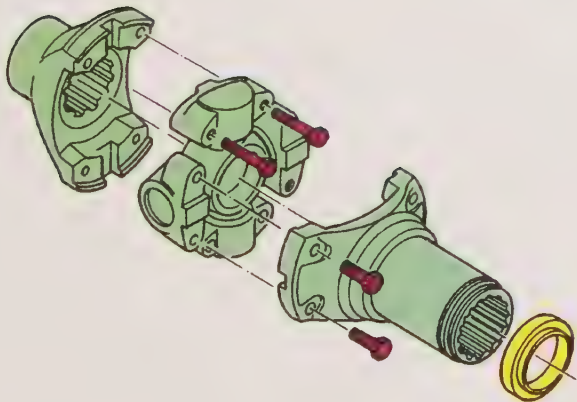
The conventional U-joint is almost always driving at an angle. As a result of the angle, the speed of the drive shaft will rise and fall for any given transmission output



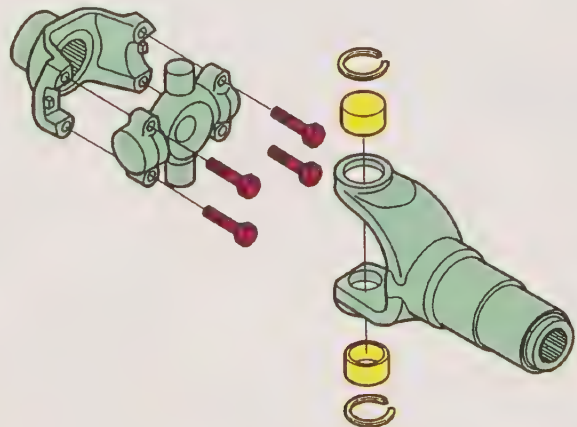
Full-Round



Easy Service (1/2 Round)



Wing Series Permalube



RPL Series Permalube

Figure 12-11. The universal joints shown here are used on some large trucks and SUVs. Although they are larger and heavier than conventional U-joints, they are often easier to remove and disassemble. (ArvinMeritor)

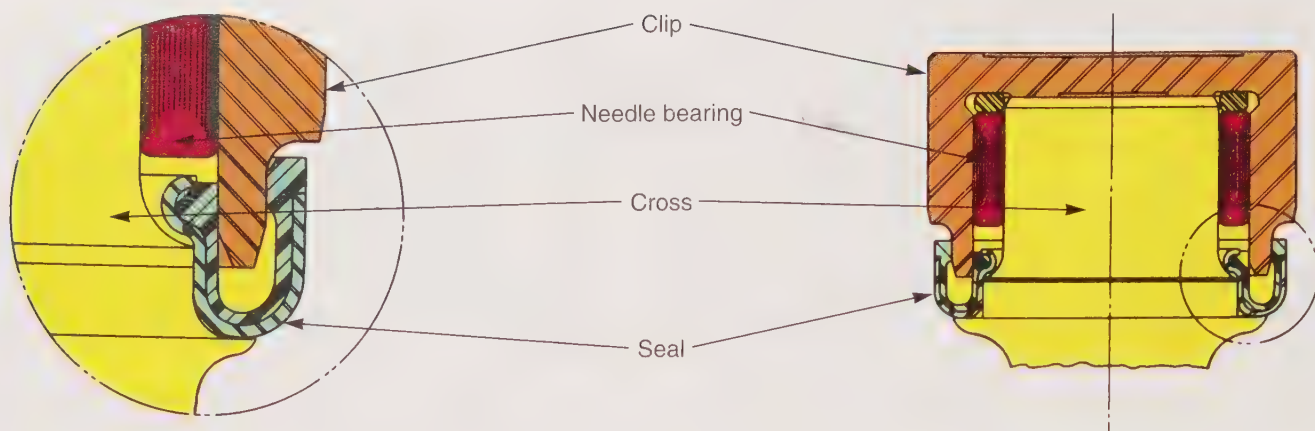


Figure 12-12. The construction of the bearing cup seal keeps grease in and keeps dirt and water out. The seal can withstand slight internal pressure, but it will be blown out and ruined by overgreasing. (Dana)

shaft rpm. The drive shaft speed will rise and fall two times for every revolution, as shown in **Figure 12-13**.

The fluctuation in drive shaft speed is created at the front U-joint. It is canceled at the differential pinion yoke by the rear U-joint if the U-joint at the output shaft and drive shaft and the U-joint at the drive shaft and differential pinion yoke form equal angles. It is also cancelled if the U-joints are aligned in phase. When in phase, the ears on the front drive shaft yoke align with those on the rear drive shaft yoke, and those on the slip yoke align with those on the pinion yoke. Under these circumstances, the reaction at the rear U-joint will be opposite that at the front U-joint. Therefore, the drive shaft speed fluctuation produced by the front U-joint is canceled by the rear U-joint. The result is a fairly

constant rotation and a smooth transfer of power delivered to the differential drive pinion gear.

Constant-velocity U-joints

One disadvantage of the conventional U-joint is the uneven transfer of power through angles between drive and driven shafts, resulting in vibration and other problems. Aligning the drive shaft yokes reduces the problem on most rear-wheel drive cars and trucks. However, some larger rear-wheel drive vehicles use a more complex arrangement to further reduce vibration.

Constant-velocity U-joints, or **CV joints**, provide an extremely smooth power transfer. However, they are more complicated than the conventional U-joint. There are several different types of CV joints.

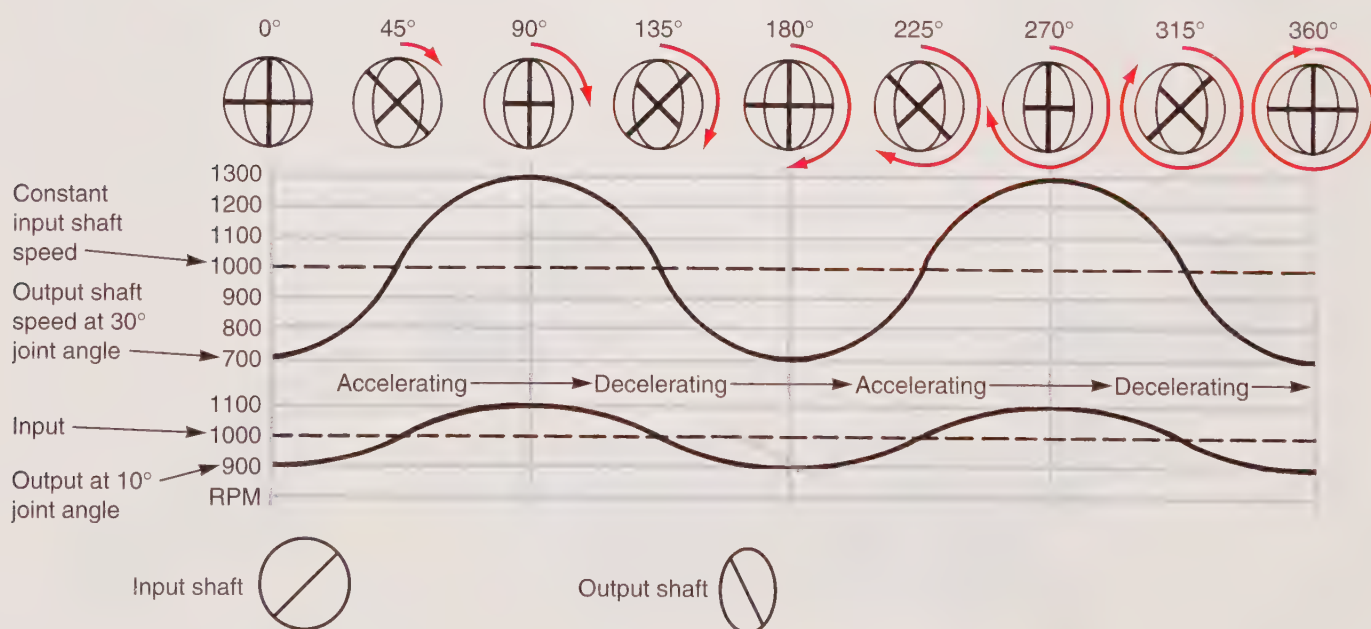


Figure 12-13. Due to the construction of cross-and-roller universal joint, the drive shaft (output shaft in this illustration) speeds up and slows down twice during every revolution. The range of speed fluctuation increases as the joint angle increases. This may be seen by comparing the output shaft speeds for the 10° and 30° joint angles given in this illustration. Note that if the joint angles are excessive, vibration may be felt in the passenger compartment. (Perfect Circle)

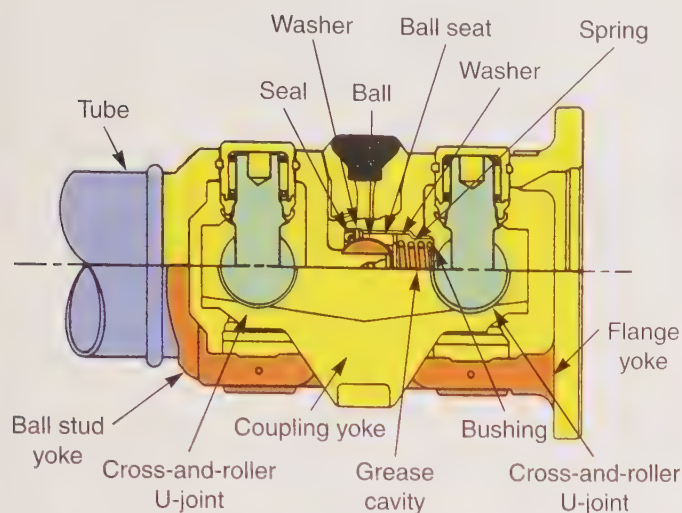


Figure 12-14. This detailed view of a typical double Cardan U-joint shows that it is simply two Cardan U-joints connected to each other through a center yoke. The universal joints and the ball-and-socket connection require periodic lubrication. (General Motors)

A CV joint used on some rear-wheel drive automobiles is the **double Cardan U-joint**, **Figure 12-14**. This joint is constructed with a cross-and-roller U-joint at each end of a special coupling yoke, called a center yoke. A central ball-and-socket connection acts as a centering device. The name of this CV joint comes from the two Cardan U-joints that are used. A drive shaft assembly may use one double Cardan U-joint and one conventional U-joint, or it may use two double Cardan U-joints.

Figure 12-15 illustrates the action of the double Cardan U-joint. The construction of this joint allows a fluctuating output speed to be compensated for within the center yoke. This CV joint design splits the drive shaft assembly angle equally between the two shafts. This is accomplished through the ball-and-socket centering device. The equal drive shaft assembly angles offset each other, and speed changes at the output of the first cross-and-roller U-joint are counteracted by speed changes at the second.

Another type of universal joint designed for constant velocity is the **ball-and-trunnion U-joint**. This design is not used on modern vehicles, but it was popular on some older vehicles. In addition to allowing the drive shaft assembly to bend, this joint also allows fore-and-aft (forward and backward) movement of the propeller shaft. Therefore, a separate slip yoke is not necessary when this type of joint is used.

The **Rzeppa joint** is a type of CV joint that uses a series of ball bearings that are held by a slotted cross assembly. The balls are held in slotted channels and rotate in any direction. The Rzeppa joint can transmit power through changing angles by allowing the balls to move up and down on the cross as torque is transmitted through them. This type of joint is often used on front-wheel drive vehicles. It is sometimes seen on drive axles of rear-wheel

drive vehicles with independent rear suspension. Rzeppa joints will be covered in greater detail in Chapter 14.

The **tripod joint** is a type of CV joint that is often used as the inner bearing on front-wheel drive vehicles. It resembles a ball-and-trunnion U-joint, but it uses a three-pointed cross pin. (This will also be explained in greater detail in Chapter 14.) This joint is sometimes used on drive axles of rear-wheel drive vehicles with independent rear suspension.

Differential Pinion Yoke

The **differential pinion yoke** connects to the drive pinion gear in the rear axle assembly. The yoke has internal splines that fit external splines on the drive pinion gear shaft. The yoke is held to the shaft by a large locknut.

On some rear axle assemblies, the yoke is a two-piece assembly, consisting of two mating flanged sections. This particular design is referred to as a **differential pinion flange** or a **companion flange**. One flange holds the rear universal joint, and the other connects to the pinion gear. The arrangement attaches the rear universal joint to the pinion. The flange is purposely heavy to absorb shock and act as a vibration damper. The differential pinion yoke/flange is covered in more detail in Chapter 16.

Classes of Drive Shaft Assemblies

Drive shaft assemblies can be divided into two general classes: the Hotchkiss drive and the torque-tube drive. The Hotchkiss version is the most common. The torque-tube design was used on some makes of automobiles for many years. It is uncommon at present.

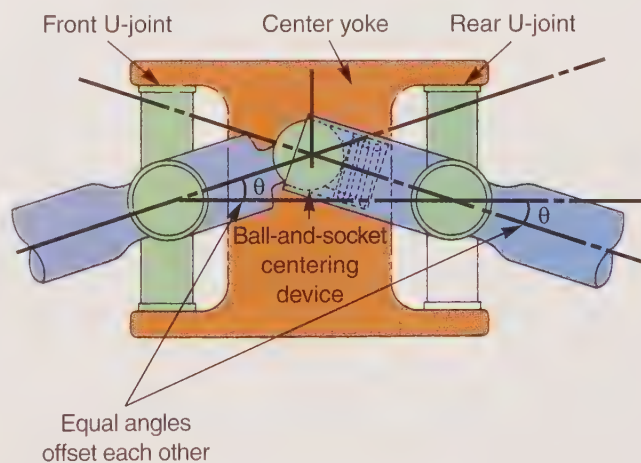


Figure 12-15. The construction of the double Cardan U-joint cancels out speed fluctuation in the drive shaft assembly. Speed fluctuation caused by the front universal joint is canceled out by the rear universal joint because the drive shaft assembly angles (θ in illustration) are equal. The centering ball keeps both shafts aligned, and all speed fluctuations occur in the center yoke. (General Motors)

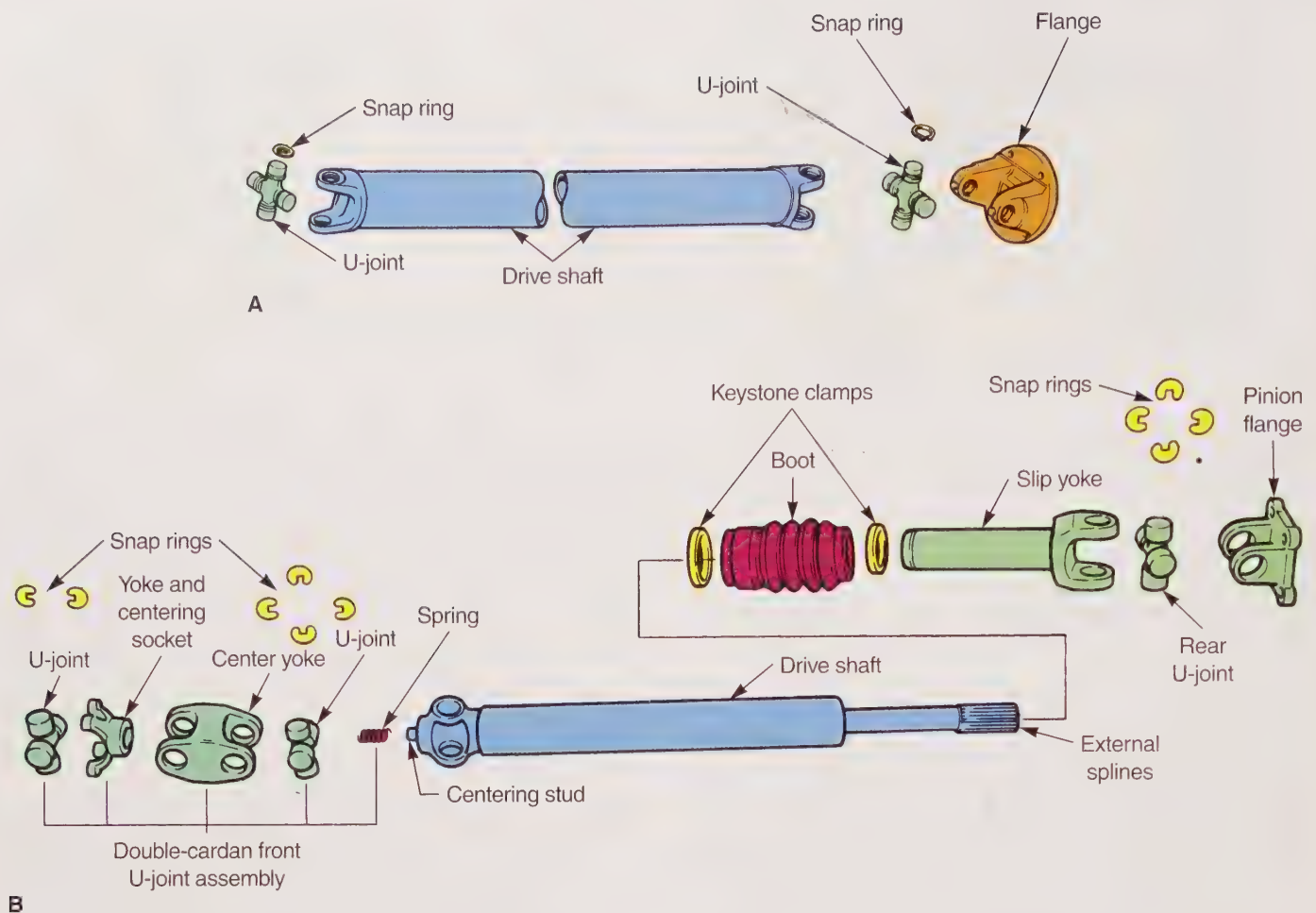


Figure 12-16. A—Hotchkiss drive uses this type of drive shaft. It is sometimes called an open drive shaft since it is not enclosed in a tube or housing. Most Hotchkiss designs have two universal joints, one at each end of the shaft. B—Note the variation of the Hotchkiss drive. It uses a CV joint at the front to reduce vibration. An unusual feature of this drive is that the slip yoke is part of the drive shaft. (Fiat, Ford)

Hotchkiss Drive

The **Hotchkiss drive** as opposed to an enclosed shaft uses an open shaft with two or more U-joints, **Figure 12-16A**. Thus far, this type has been the focus of the chapter—a single shaft, a slip yoke and U-joint at the transmission, and a U-joint at the differential. The drive shaft assembly can flex at both ends of the drive shaft—at the front and the rear universal joints. The Hotchkiss drive is lighter, cheaper to produce, and easier to service than the torque-tube drive. In late-model rear-wheel vehicles, it is used almost exclusively. The true Hotchkiss drive is always used with rear leaf springs. When coil springs are used to attach the rear axle to the vehicle, the drive shaft assembly is called a **Salisbury drive**. However, the term Hotchkiss is applied interchangeably to both types of drive shaft assemblies.

A variation of the Hotchkiss drive is shown in **Figure 12-16B**. A constant-velocity U-joint is used. The slip yoke is at the rear of the shaft, instead of at the front where it usually is. This kind of slip yoke usually has one spline that is larger than the others. This ensures the parts get reassembled in their original alignment.

Torque-Tube Drive

The **torque-tube drive** has a drive shaft that is solid steel and enclosed in a tube. The torque-tube drive is designed to control rear-end torque. The tube is solidly connected to the rear axle assembly with bolts. In many designs, it is connected to the transmission through a ball joint, about which it pivots.

The steel drive shaft connects to the transmission output shaft through a universal joint. The other end of the shaft connects to the drive pinion gear through a coupling or splined connection. There is a universal joint at only one end. Often, it is a ball-and-trunnion U-joint.

The drive shaft assembly can flex only at the front end of the drive shaft, at the U-joint between the transmission and the drive shaft. The rear axle assembly moves up and down in an arc as it pivots about the U-joint, and the distance between the transmission and rear axle assembly is always the same. Since the drive shaft length does not have to change, a slip yoke is not needed.

The torque-tube drive was used on many vehicles. It was discontinued because the tube added extra weight to the

vehicle, and because it was necessary to remove the tube and rear axle assembly to gain access to the universal joint or drive shaft. Today only Corvette uses the torque-tube drive.

Two-Piece Drive Shafts

A **two-piece drive shaft** is a drive shaft that is divided into two sections, with a universal joint between the front and rear sections. A type of two-piece drive shaft is shown in **Figure 12-17**. The two-piece drive shaft uses three universal joints. These universal joints are identical to those used with a one-piece drive shaft. With three universal joints, drive shaft assembly angles are reduced at each universal joint compared to what they would be if only two were used. This reduces vibration.

Two-piece drive shafts were once used when the design of the vehicle frame made it impossible to use a single drive shaft. During the 60s and 70s, the two-piece drive shaft was discontinued on all vehicles except large trucks and some long-bed pickups. Increased popularity of large SUVs has caused the two-piece drive shaft to again become common.

The two-piece drive shaft is a variation of the Hotchkiss drive. The two shafts are steel tubes with yokes on all four ends. They resemble shorter versions of the single drive shaft. See **Figure 12-18**.

Two-piece drive shafts require a center support bearing to hold the rear of the front shaft and the front of the rear shaft, **Figure 12-19** and **Figure 12-17**. The inner race of the bearing is pressed on or bolted to the front drive shaft. The bearing is usually greased and sealed at the factory. The outer race of the bearing is held by a thick rubber ring that is fastened to the vehicle frame or underbody by a bracket. The rubber ring acts as a cushion to absorb vibration.

The two-piece drive shaft must have a slip yoke. Since in many designs the front shaft is kept from moving back and forth by the center support bearing, the slip yoke is usually installed behind the support bearing. Some two-piece drive shafts have two slip yokes.

Drive Shaft Assembly Angles

All rotating parts have an **axial centerline**. This is the central axis around which the rotating parts revolve, or the **rotational axis**. Sometimes, several devices with rotating parts are coupled together. An example of this is the vehicle transmission, drive shaft, and rear axle assembly.

When rotating parts are coupled together, care must be taken to ensure that the centerlines are closely matched. **Perfect alignment**, **Figure 12-20A**, would mean that all of the

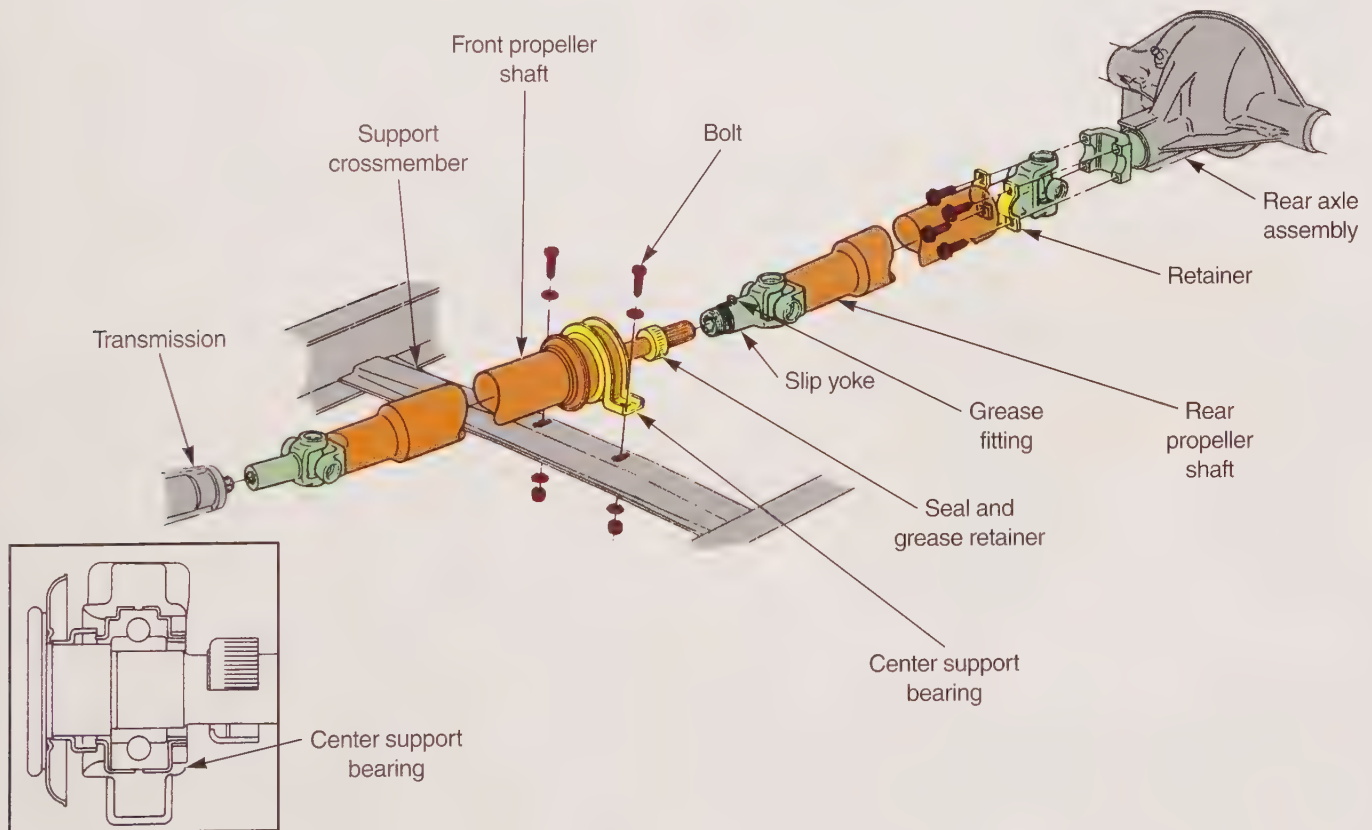


Figure 12-17. The two-piece drive shaft consists of two drive shafts and three universal joints. A center support bearing keeps the drive shafts aligned. This system is used to reduce vibration or when the frame design prevents the use of a single drive shaft. (General Motors)

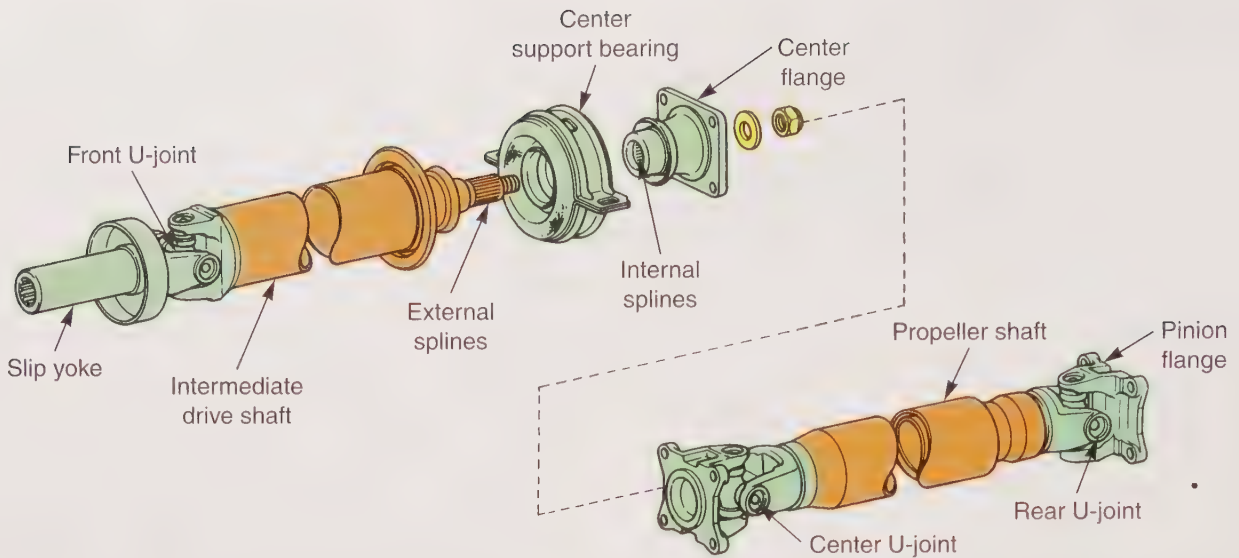


Figure 12-18. Note the relative positions of the parts of a two-piece drive shaft. Also, note the front, center, and rear universal joints. The design pictured has two slip yokes—one up front and one at the rear of the front shaft, behind the center support bearing. The bearing is solidly mounted and will not allow axial movement of the front shaft. The rear slip yoke permits back-and-forth movement of the rear shaft. The front slip yoke is used to simplify shaft installation.

centerlines line up exactly, forming one long centerline. Under actual conditions, perfect alignment is seldom achieved. Any deviation from a perfect alignment means that there is an angle between the centerlines, as shown in **Figure 12-20B**.

Figure 12-20B shows the **drive shaft assembly angles**, or **operating angles**, on a front-engine, rear-wheel

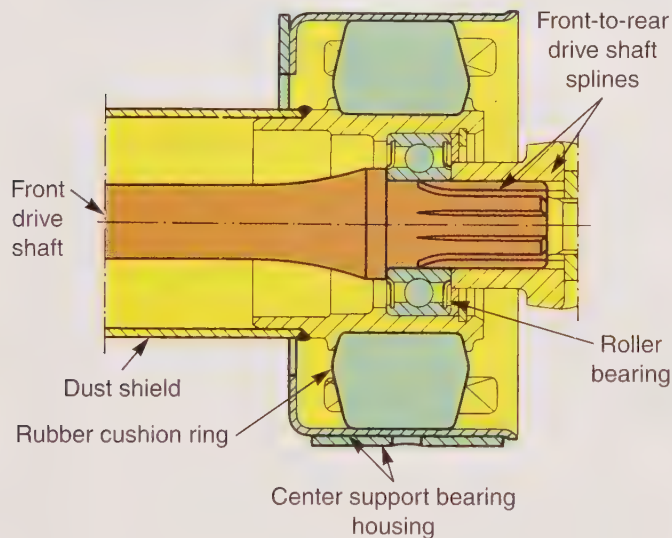


Figure 12-19. The center support bearing used with a two-piece drive shaft is usually a permanently greased ball bearing. Some heavy-duty bearings can be greased through a fitting. The bearing is installed near the rear of the front drive shaft. Most center support bearings are pressed on the shaft, but some may be held by bolts or some other kind of fastener. Some bearings simply slip onto the shaft. (Fiat)

drive vehicle. These are the angles between the centerlines of the transmission output shaft and drive shaft and between the drive shaft and the drive pinion gear shaft. The drive shaft assembly angles are also referred to as the **U-joint angles** because the inclination of the drive shaft assembly changes at the universal joints. The angles are measured at the front and rear U-joints and compared to specifications.

Note that the vehicle manufacturer's specification for U-joint angle is usually small—about 1° or 2° . If the angle is greater than specified, the speed fluctuations of the driven shaft increase in range. The drive shaft may have an objectionable vibration. If a U-joint angle becomes too large, the joint itself can break.

Drive shaft assembly angles are determined by carefully measuring the inclinations of the transmission output shaft, drive shaft, and drive pinion gear shaft. The drive shaft assembly angles are then determined from these measurements. Chapter 15 contains detailed procedures for checking drive shaft assembly angles.

Note that since the rear axle assembly moves in relation to the transmission, the drive shaft assembly angle varies with any movement of the vehicle suspension. Factors that affect the suspension and, therefore, the drive shaft assembly angle include added weight in the vehicle, road conditions (bumps, dips, and pot-holes), vehicle acceleration or deceleration, and suspension system wear or alterations. For this reason, it is important that the original drive shaft assembly angles be kept as close as possible to the manufacturer's specifications.

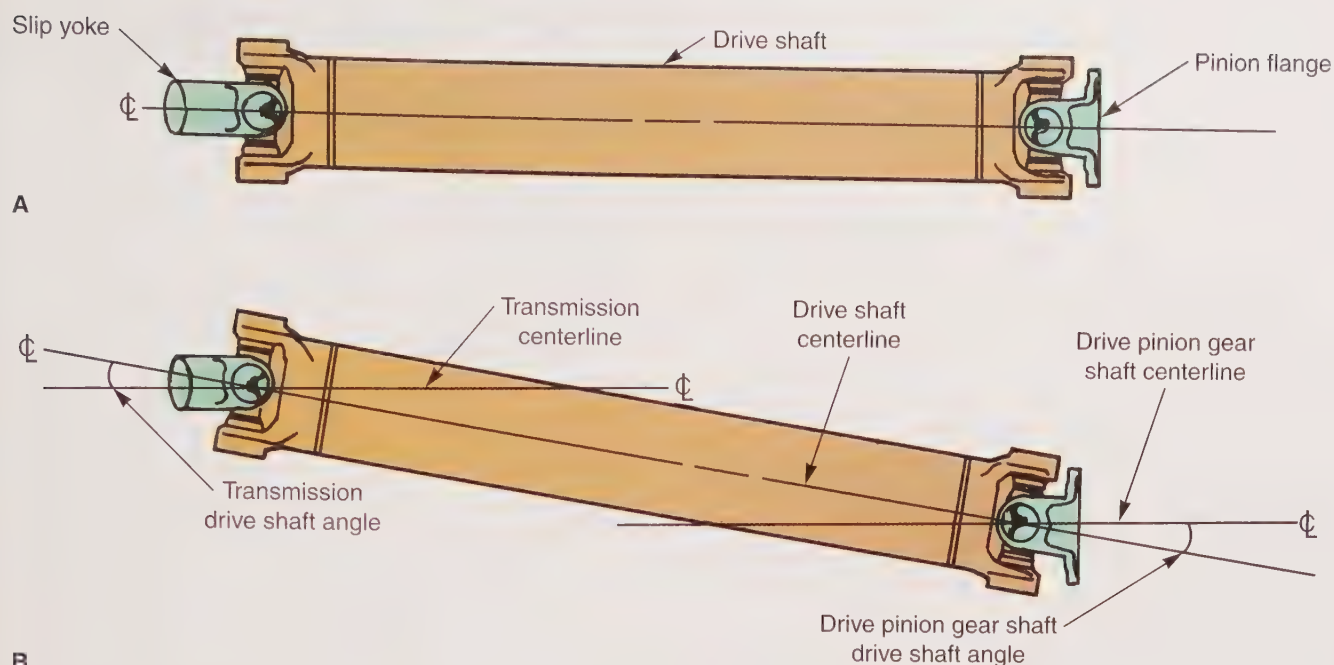


Figure 12-20. Drive shaft assembly angles. A—The ideal drive shaft assembly angle would be 0° , or perfect alignment. B—In actuality however, the drive shaft assembly has some angles due to the relative placement of the transmission and rear axle assembly.

Summary

The drive shaft assembly must transfer power from the transmission to the rear axle assembly. At the same time, it must make changes in angle and length to compensate for changes in position of the rear axle assembly.

The drive shaft assembly is composed of the drive shaft, universal joints, slip yoke, and balance weights. The shaft is a one-piece steel tube. It is hollow to reduce weight. The other drive shaft assembly parts are attached to the shaft.

The drive shaft must be rugged to absorb shocks. It must be carefully balanced to reduce vibration.

The slip yoke is a splined shaft that is designed to slide on the transmission output shaft. This sliding action allows it to change length as required.

The universal joints allow the drive shaft assembly angles to change as the rear axle assembly moves over the road surface. The most common universal joint is the cross-and-roller, or Cardan, type. It consists of a cross and four bearing cups. The cups attach to the drive shaft yokes by various attachment methods. Needle bearings between the cross trunnions and cups reduce friction. There may be a grease fitting to allow lubrication of the needle bearings.

The cross-and-roller U-joint can cause drive shaft vibration. Angles between two shafts result in the driven shaft speeding up twice and slowing down twice during each revolution. The cross-and-roller U-joint must be carefully installed to reduce vibration.

To further reduce vibration, some other kinds of universal joints are used. The double Cardan U-joint is

composed of two cross-and-roller U-joints connected by a center yoke. Vibration forces are canceled within this yoke.

The differential pinion yoke attaches the rear universal joint to the rear axle assembly. It may be bolted directly to the drive pinion gear shaft, or it may be a separate part bolted to the pinion flange.

The two major classes of drive shaft assemblies are the Hotchkiss and the torque-tube. The Hotchkiss drive is the most common. It is often called an open drive shaft assembly. The Hotchkiss design has at least two universal joints.

The two-piece drive shaft is a type of Hotchkiss design. It has two separate shafts and three universal joints. The slip yoke is usually between the front and rear shafts. Two-piece shafts have a center support bearing at the rear of the front shaft. This ball bearing is factory greased and sealed. It is attached to the vehicle through a flexible mounting to reduce the transfer of drive shaft vibration.

Proper drive shaft assembly angles are critical to vibration reduction and long component life. These angles must be as close to zero as possible.

Review Questions—Chapter 12

Answer the following questions using the information provided in this chapter.

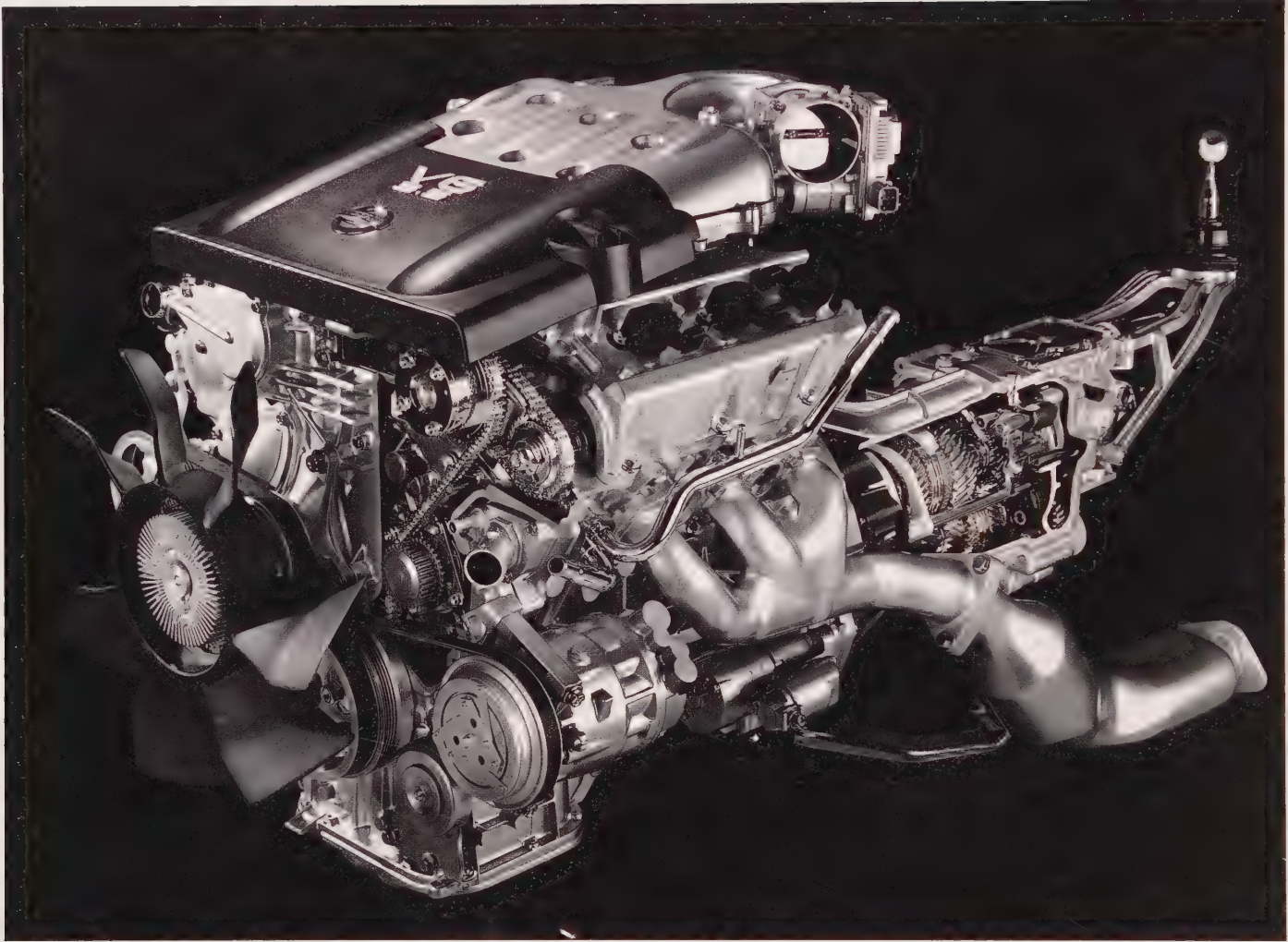
1. Drive shaft ____ is measured from center to center of each yoke hole.
2. What is a slip yoke?

3. Most rear-wheel drive vehicles use _____.
 - (A) cross-and-roller U-joints
 - (B) Cardan U-joints
 - (C) conventional U-joints
 - (D) All of the above.
4. The cross ends of a Cardan U-joint are called _____.
5. Which type of universal joint uses several steel balls to allow rotation?
 - (A) Ball-and-trunnion.
 - (B) Cardan.
 - (C) Rzeppa.
 - (D) Pivotal.
6. A(n) _____ drive has a drive shaft that is solid steel and enclosed in a tube.
7. Hotchkiss drive uses a(n) _____ shaft with two or more _____.
8. Where is a center support bearing used, and why?
9. What are U-joint angles?
10. Give four factors that affect drive shaft assembly angles.
5. Each of the following is a drive train component consisting of a center spider and four cups containing needle bearings *except*:
 - (A) Cardan U-joints.
 - (B) conventional U-joints.
 - (C) cross-and-roller U-joints.
 - (D) double Cardan U-joints.
6. Fluctuation in drive shaft speed is created at the _____.
 - (A) rear U-joint
 - (B) front U-joint
 - (C) slip yoke
 - (D) axial centerline
7. A double Cardan U-joint design splits the drive shaft assembly angle equally between two shafts. Technician A says that this is accomplished through the joint's ball-and-socket centering device. Technician B says that the joint's center yoke is responsible. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
8. Each of the following universal joints is designed for constant velocity *except*:
 - (A) a tripod joint.
 - (B) a Rzeppa joint.
 - (C) a ball-and-trunnion joint.
 - (D) a cross-and-roller joint.
9. In the rear axle assembly, the differential pinion yoke connects the _____.
 - (A) slip yoke
 - (B) pinion flange
 - (C) drive pinion gear
 - (D) two-piece drive shaft
10. When comparing drive shaft assemblies, the Hotchkiss drive can be described as each of the following *except*:
 - (A) easier to service.
 - (B) using an enclosed shaft.
 - (C) lighter in weight.
 - (D) cheaper to produce.
11. Since the drive shaft length of a torque-tube drive does not have to change, which of these is *not* needed?
 - (A) Slip yoke.
 - (B) Pinion yoke.
 - (C) Front U-joint.
 - (D) Pinion flange.

ASE-Type Questions—Chapter 12

1. On rear-wheel drive vehicles, the transmission and the rear axle assembly are connected by the _____.
 - (A) drive shaft assembly
 - (B) output shaft
 - (C) pinion flange
 - (D) drive pinion gear
2. Each of the following is a part of the drive shaft assembly *except*:
 - (A) a slip yoke.
 - (B) a drive shaft.
 - (C) a drive pinion gear.
 - (D) U-joints.
3. The drive shaft assembly transfers power from the transmission to the _____.
 - (A) axial centerline
 - (B) torque-tube drive
 - (C) front axle assembly
 - (D) rear axle assembly
4. Which of the following is used where the drive shaft assembly enters the rear of the transmission, allowing the drive shaft to change its effective length?
 - (A) U-joint.
 - (B) Slip yoke.
 - (C) Companion flange.
 - (D) Differential pinion yoke.

12. A two-piece drive shaft uses _____.
(A) one U-joint
(B) two U-joints
(C) three U-joints
(D) no U-joints
13. Technician A says that the slip yoke has external splines that mate with the transmission output shaft. Technician B says that the slip yoke fits closely with the transmission extension bushing and rear seal. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
14. Technician A says that all cross-and-roller U-joints have grease fittings. Technician B says that some universal joints are sealed at the factory and cannot be greased unless they are disassembled. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
15. Each of the following is used to hold bearing cups in place *except*:
(A) retainer snap rings.
(B) bolted straps.
(C) anaerobic sealer.
(D) injected plastic.



A 6-speed transmission and 3.5-liter engine from a front-engine, rear-wheel drive vehicle. The added gear ratios of a 6-speed transmission improve engine performance and fuel economy. Note that the engine is longitudinally mounted. (Nissan)



Chapter 13

Drive Shaft Assembly Problems, Troubleshooting, and Service

After studying this chapter, you will be able to:

- ☐ Identify drive shaft assembly related problems.
- ☐ Inspect a drive shaft assembly both visually and with instruments.
- ☐ Locate the source of typical drive shaft assembly problems.
- ☐ Perform in-car drive shaft assembly service procedures.
- ☐ Remove a drive shaft assembly from a vehicle.
- ☐ Service universal joints.
- ☐ Install a drive shaft assembly in a car.

Technical Terms

Backlash

Axial vibration

Radial vibration

Inclinometer

Shim

Introduction

Although some of the newest drive shafts of rear-wheel drive vehicles are composites of graphite and aluminum, most are hardened-steel tubes. These shafts are rugged and do not wear out. Drive shafts can, however, become bent or unbalanced. This can happen from such things as an accident, driving over very rough ground, or anything else that would cause a heavy blow to the shaft.

Most drive shaft assembly problems are caused by the universal joints. U-joints installed at the factory normally do not have grease fittings; they cannot be greased without being taken apart. Eventually, the original grease washes or leaks out, and the U-joints begin to wear and become noisy. Worn U-joints are a common problem.

At first, a loose or noisy U-joint will not cause other problems. However, if the vehicle is driven for long periods with a defective U-joint, the joint will wear until it finally comes apart. When this happens, the drive shaft assembly will come undone at the transmission or at the rear end (rear axle assembly). The vehicle will then be stranded.

When a rotating drive shaft becomes disconnected, it can damage itself and the underside of the vehicle. The drive shaft will usually get bent or dented and have to be replaced. Fuel and brake lines, electrical components, and rear end parts can also be damaged or destroyed. For these reasons, you should replace a defective U-joint as soon as you know about it.

This chapter will enable you to diagnose, inspect, and service U-joints—and drive shaft assemblies, in general. **Figure 13-1** shows the various places where drive shaft assembly problems occur. Study them carefully.

Drive Shaft Assembly Problems and Troubleshooting

Drive shaft assembly malfunctions can result from misaligned parts, improper machining, and external damage

to the drive shaft. They are sometimes difficult to troubleshoot, since the problems they cause are similar to problems caused by other assemblies. To arrive at a proper diagnosis, check every part of the drive shaft assembly—and assume nothing. Also, check other possible causes of the problem. Examples include a bent wheel or a cupped tire, which can cause vibrations similar to those caused by a bent drive shaft.

Always try to obtain as much information as possible before beginning any repairs. Find out exactly why the vehicle was brought in for service. Whenever possible, test-drive the vehicle with the owner to make sure you agree about the nature of the problem. Also, drive shaft troubleshooting charts are available. Be sure to consult these for possible solutions.

Check out the easiest possible solutions before proceeding to more difficult solutions. For instance, if a grease fitting is provided, a squeaking U-joint can sometimes be silenced by greasing the joint. If the grease does not help, then the U-joint should be replaced.

There are two major types of drive shaft assembly problems:

- ☐ **Abnormal noise**—caused by worn U-joints or bearings.
- ☐ **Drive shaft assembly vibration**—caused by worn or damaged parts or shaft imbalance.



Note: Drive shaft assembly problems can lead to leaks of transmission oil or U-joint bearing grease.

Abnormal Noise

Abnormal noises in the drive shaft assembly include squeaks, clunks, whines, and similar sounds. These noises can usually be traced to the defective part without much difficulty.

Squeaks are usually caused by a dry U-joint. They are usually heard when driving in reverse. Squeaking is often an early indication that a U-joint is going bad.

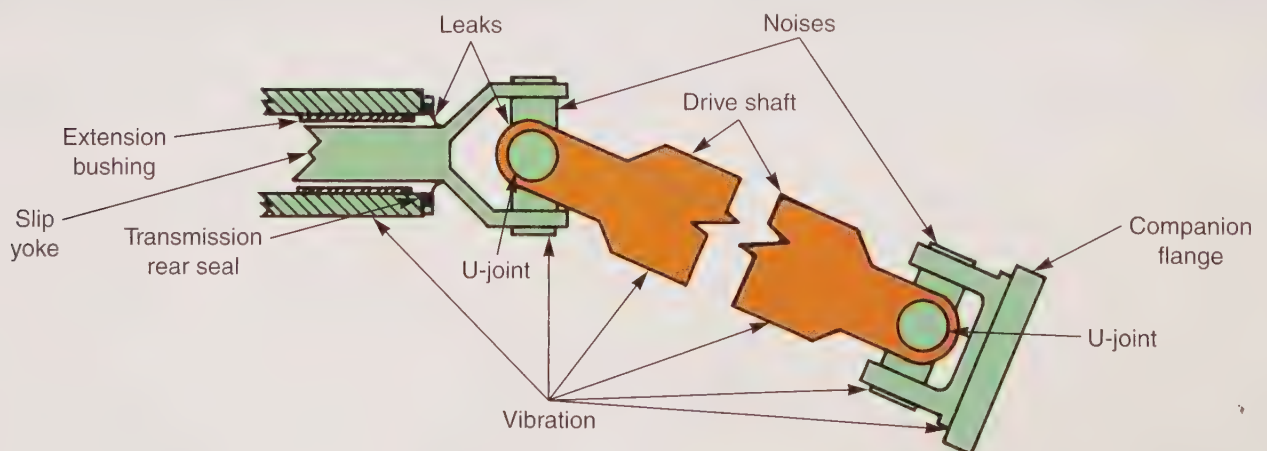


Figure 13-1. Note the typical problems of a drive shaft assembly.

A clunking noise when reversing direction or at low speeds under light acceleration can be caused by too much backlash somewhere in the drive train. Note that in Chapter 4, backlash was defined in relation to gears. In a broader sense, **backlash** is a condition of clearance or movement between two closely mating mechanical parts. It is the amount of play between these parts.

Before checking the drive shaft assembly, always make sure the excessive backlash is not inside the differential. If the differential is okay, check the drive shaft assembly, concentrating on the U-joints, slip yoke, and center support bearing (if so equipped). Also, check the transmission extension bushing.

Excessive backlash often shows up in U-joints. Worn U-joints can sometimes be spotted by grease leaking from them or by excessive play between parts when wiggling or rotating the drive shaft. If the drive shaft has a center support bearing, make sure the attaching bolts have not worked loose. The extension bushing can be checked for wear by trying to wiggle the slip yoke while it is in position. Too much play in any one of these parts causes a clunking noise.

Clunks, in rare cases, are caused by worn splines on the slip yoke or on the transmission output shaft. Check the slip yoke and output shaft by removing the drive shaft assembly and visually inspecting the splines for wear. Check all other possibilities first, however.

Rubbing, whining, or whirring noises can be caused by the drive shaft rubbing on a stationary part of the vehicle (the exhaust system, for example) or by a defective center support bearing. One clue that a drive shaft is rubbing is a change in sound when the vehicle is driven over bumps.

Drive Shaft Assembly Vibration

Vibration is the rapid back-and-forth or side-to-side movement of a rotating part. Drive shaft assembly vibrations can originate from any of its associated parts.

In terms of the drive shaft, there are two types of vibration—axial and radial. **Axial vibration**, **Figure 13-2**, is a lengthwise, or back-and-forth, movement of the shaft along its rotational axis. Back-and-forth movement is strictly limited by the design tolerances built into the drive train. It does not cause problems unless the U-joints are very worn or loose. **Radial vibration** is a side-to-side movement of a rotating

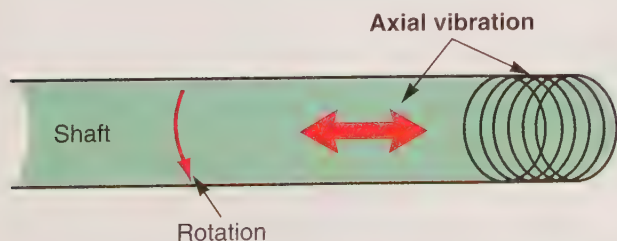


Figure 13-2. Axial vibration is a back-and-forth movement in relation to shaft rotation. It is not usually a problem on drive shafts unless U-joints are severely worn.

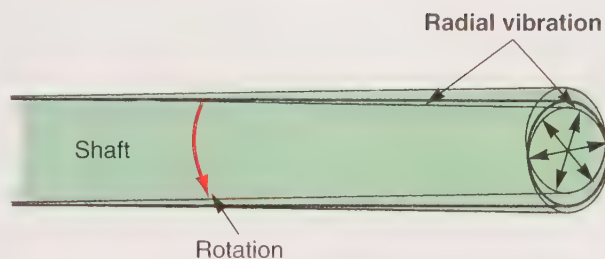


Figure 13-3. Radial vibration is a more common drive shaft vibration problem. It is a side-to-side movement in relation to shaft rotation. It can often be felt in the passenger compartment. It can be caused by worn U-joints or by a bent or otherwise damaged drive shaft. Misalignment or anything else that contributes to an unbalanced condition can cause vibration.

part along its rotational axis. See **Figure 13-3**. It is the most common cause of vibration in an automotive drive shaft.

Drive shaft vibrations occur whenever the vehicle is moving, and the vibrational pulses occur at regular intervals. The vibrations can be measured in terms of frequency, or cycles per second, and amplitude. Note that the frequency varies in direct proportion to drive shaft speed. Also, the greater the amplitude, or deviation from exact center, the stronger the vibration.

Figure 13-4 graphically represents the vibration of the shaft shown to its left. The graph depicts one cycle of vibration. Points B and C represent the maximum distance of shaft deviation from the exact center. The cycle begins with the shaft centered at point A. As the shaft turns, it goes through point B, reverses direction, and passes through point A to point C. At point C, it reverses again and returns to point A. The number of cycles in a given time period (frequency) increases with drive shaft speed.

Drive shaft assembly vibrations can be felt in the steering wheel, brake pedal, or in the vehicle body. As a first step, make sure the vibration is not caused by problems in the tires, wheels, or brake system.

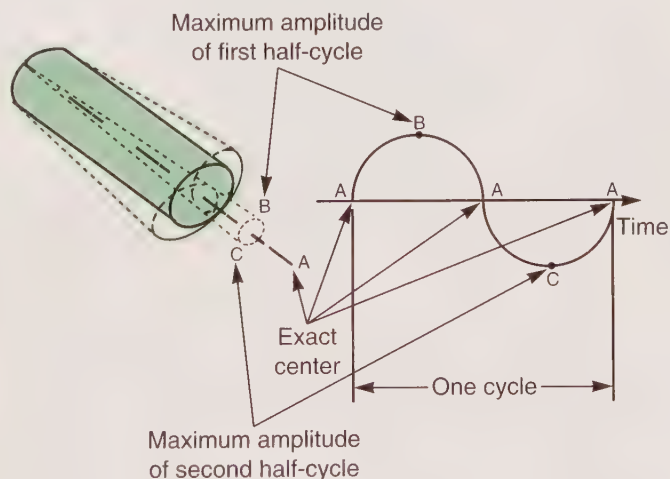


Figure 13-4. One cycle of vibration is represented by this waveform. Frequency is the number of cycles occurring in a certain period of time. Amplitude is the strength of the vibration.



Note: The drive shaft turns at higher speeds than the wheels, and as a result, drive shaft vibration will occur at a higher frequency than wheel- and tire-produced vibration.

Sometimes, a vibration can be traced to an engine problem, such as a dead cylinder or flywheel imbalance. One way to check this is to shift the transmission into Neutral at cruising speeds and allow the engine to idle. If the vibration decreases, the problem is in the engine. If the vibration stays the same, the problem is elsewhere.

Once you are sure the source of the problem is in the drive shaft assembly, check the U-joints for excessive backlash or other signs of wear. Worn U-joints, especially the front joint, will cause a vibration when the vehicle is accelerated between 30 and 40 mph (48 and 64 km/h).

Check for dirt or undercoating stuck to the drive shaft. Foreign material on the outside of the drive shaft can be easily spotted and removed. Check for missing balance weights. Also, check to see if the shaft is bent. Any of these conditions can cause drive shaft imbalance, resulting in vibration.

Other possible causes of vibration are a loose fit between drive shaft assembly yokes and U-joint bearing cups or a broken lug on one of the yokes. Vibration can also be caused by a defective center support bearing on vehicles with two-piece drive shafts. A loose or worn center support bearing will almost always be noisy.

The slip yoke or transmission extension bushing can also wear out, causing a vibration that is at its worst when the vehicle is accelerated. A worn slip yoke or bushing will almost always cause a leak at the transmission rear seal.

Drive Shaft Assembly Service Precautions

You should always observe safety rules and certain other precautions when working around drive shaft assemblies. To review information that was highlighted in Chapter 2, some general precautions for drive shaft assembly service are:

- ❑ Always support the vehicle in a safe manner. If a hoist is not available, support the ends of the rear axle housing on jack stands after raising the vehicle with a suitable jack. *Never* depend on any jack to keep the vehicle raised while working under it.
- ❑ Stay away from rotating drive shaft assembly parts and rear wheels when the engine is running.
- ❑ Do *not* wear loose clothing or jewelry that could be caught by the rotating drive shaft assembly. Long hair should be tied up or otherwise secured.
- ❑ Wear eye protection whenever you are under the vehicle! (This is very important if you must hammer on any part of the shaft.)

- ❑ Make sure the engine won't be accidentally started when you are working on or closely inspecting the drive shaft.
- ❑ The drive shaft is heavy and awkward. Do *not* allow it to drop when attachments to the rear axle assembly are removed. This could damage the shaft or transmission extension housing. It could also hurt you!
- ❑ Make sure you do *not* damage the drive shaft while making other repairs. You can damage a drive shaft by dropping it, striking it against solid objects, or by clamping it too tightly in a vise.
- ❑ It is easy to deform a drive shaft yoke when removing a U-joint. Carefully align and support all bearing removal tools before pressing or hammering. Make sure the drive shaft is securely held before beginning repairs.
- ❑ Always reinstall the bearing cup retainer clips. A retainer clip that will not seat is a symptom of another problem, such as a misplaced bearing needle or a deformed yoke. A bearing cup without a retainer clip will be thrown out of the yoke at normal speeds.

Drive Shaft Assembly Inspection

Having gathered preliminary information from the vehicle owner, taken a test-drive, and consulted a troubleshooting chart, the next step is to inspect the installed drive shaft assembly. This section explains the right way to inspect the drive shaft assembly. It involves performing a visual inspection and, sometimes, a measurement inspection.

Visual Inspection

Much of drive shaft assembly inspection is checking for obvious damage by visual examination. Looking under the vehicle may be all that is required to pinpoint a problem. After the source of the problem is identified, the defective part or parts may be repaired or replaced.

Drive shaft inspection

To check the drive shaft for worn parts, raise the vehicle on a hoist or place it on jack stands to gain access to the drive shaft. Place the transmission in gear. Do not apply the parking brake. Visually inspect the drive shaft for undesirable conditions, such as undercoating, dirt, dents, and missing balance weights. Also, look for cracked welds and for contact with other parts.

U-joint inspection

Look for signs of wear when checking the U-joints. To check for U-joint wear, attempt to rotate the drive shaft while watching the U-joint yokes. No movement should occur between the cross and yoke, either at the front yoke

or at the rear yoke (although the entire assembly may rotate slightly). Attempt to wiggle the shaft up and down and from side to side. Try sliding the shaft back and forth. This is shown in **Figure 13-5**. Again, no movement should occur at either U-joint. If a cross moves inside its yoke, the U-joint must be replaced.

If the U-joint passes the above inspection, visually check that all snap rings, U-bolts, or other attachments are installed tightly. Also, make sure that none of the U-joint bearing cups are loose in their yokes. Check CV joints using this same procedure.

Slip yoke and extension bushing inspection

The slip yoke and transmission extension bushing can be checked by a procedure similar to that used to check the front and rear U-joints. Try to move the slip yoke up and down and from side to side while watching the transmission extension housing. Any movement of the slip yoke should be slight. Typically, it should be no more than 1/16" (1.5 mm).

If slip yoke movement is greater than this, or if the transmission rear seal is leaking, remove the drive shaft. You can then inspect the yoke and bushing. Look for wear or scoring. The bushing will usually show much more wear than the yoke.

Center support bearing inspection

On drive shaft assemblies with a center support, check the bearing by trying to move the drive shaft yoke up and down and from side to side at the center support. There should be almost no movement between the drive shaft and bearing.

If the center support passes this test, put the transmission in Neutral and turn the drive shaft. If you feel any roughness as you turn the shaft or hear any noises from the center support bearing, the bearing should be replaced.

The bearing can also be checked with a stethoscope to detect noise with greater accuracy.



Warning: Use extreme caution when using a stethoscope to check for drive train noises. Be careful not to touch spinning parts.

Measurement Inspection

Sometimes it is necessary to use special measuring instruments to locate the source of a drive shaft assembly problem. Instruments most commonly used are the dial indicator and the inclinometer. These instruments, introduced in Chapter 3, are used to measure drive shaft radial runout and U-joint angle.

Drive shaft runout

The drive shaft should theoretically turn in a perfect circle, with every point along the shaft surface turning in a perfect circle about the rotational axis. In real life, the shaft will vary slightly from perfect rotation. This variation, or how much a part moves off-center as it rotates, is called runout. As discussed in Chapter 7, if the runout is too large, the drive shaft will be unbalanced and it will vibrate.

Most drive shafts will never require runout checking. However, sooner or later, most automotive technicians will need to perform this task when servicing a drive shaft assembly. There are two reasons to check drive shaft runout:

- ❑ If the vehicle has a high-speed vibration problem and all other causes have been eliminated.
- ❑ If the drive shaft has been struck going over rough ground or the vehicle has been in a collision.

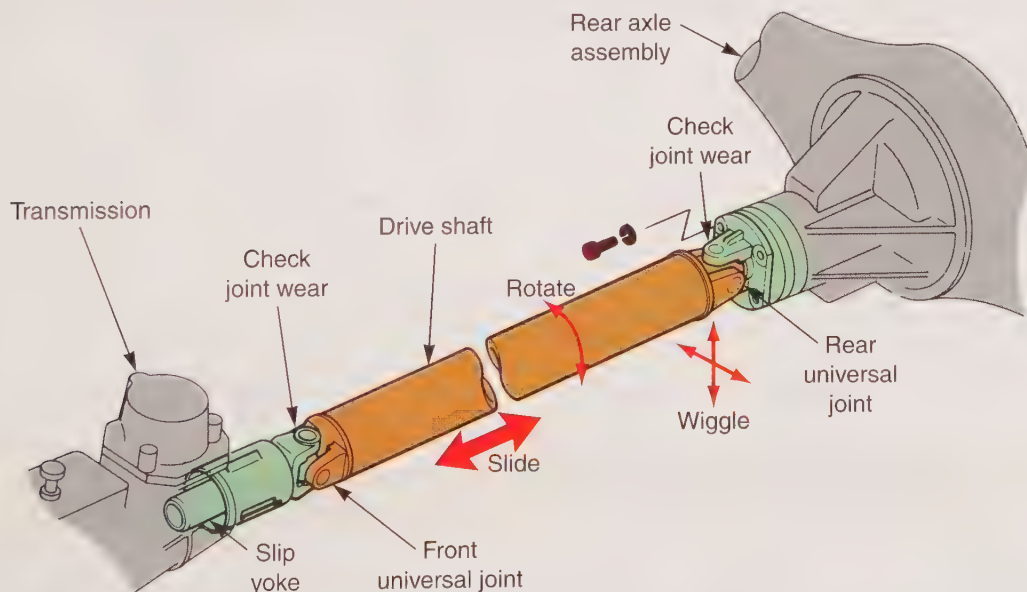


Figure 13-5. Note how to check a U-joint for wear. You should try to manually rotate, slide, and wiggle the drive shaft while watching the U-joint for movement. If the U-joint shows any movement, it must be replaced. (Mazda)

Check the drive shaft for straightness and excessive runout by first placing the transmission in Neutral. Then, raise the vehicle on a hoist or with a jack so the rear wheels are free to turn. Support the ends of the rear axle housing with jack stands, as necessary, to keep the transmission and rear axle assembly in normal alignment. The drive shaft must *not* be at a sharp angle during runout measurement.



Note: If the vehicle is raised so the rear axle assembly is hanging unsupported, the test results will not be accurate. Also, if the wheels cannot rotate freely, the runout check cannot be made.

After raising the vehicle, select a spot on the front of the drive shaft to attach a dial indicator. Manually rotate the drive shaft to make sure the spot selected does not have any weights, flat spots, weld splatter, or other variations that would cause an incorrect reading. Mount the indicator so that its plunger contacts the drive shaft. The indicator can be mounted on a tall floor stand under the car or clamped to the underside of the vehicle.

Rotate the drive shaft slowly by hand. Sometimes this can be done by turning a rear wheel. Observe and record the maximum variation of the dial indicator. Reposition the

dial indicator at the center and rear of the drive shaft and take readings in the same way as before. A two-piece drive shaft would need more readings. See **Figure 13-6**.

Maximum drive shaft runout, at any point, should typically be no more than 0.040" (1 mm). If the runout is more than specifications, remove the drive shaft from the differential pinion yoke, rotate it a half turn, and reinstall it. Then, recheck the runout.

If the runout is still too great, replace the drive shaft or send it to a drive shaft specialty shop for repairs. In some rare cases, the differential pinion flange is warped or improperly machined, causing the excessive runout problem. If the drive shaft specialty shop says the drive shaft is okay, the pinion flange should be checked. Sometimes the flange can be observed for excessive runout as it is rotated. Remove the drive shaft and turn the flange by rotating one of the tires. Excessive runout can be observed as the flange rotates. If the flange has a circular mounting surface (a separate flange holds the U-joint caps as in Figure 13-6), runout can be checked with a dial indicator. Do not remove the flange from the drive pinion gear for this check. Install the dial indicator on a solid surface under the vehicle with the pointer against the flange. Zero the indicator and slowly rotate the flange by turning a tire. Record the maximum runout as measured by the gauge. Compare the runout with the specified maximum. If the runout is excessive, remove the flange, rotate it 180° and reinstall. If runout is still excessive, replace the flange.

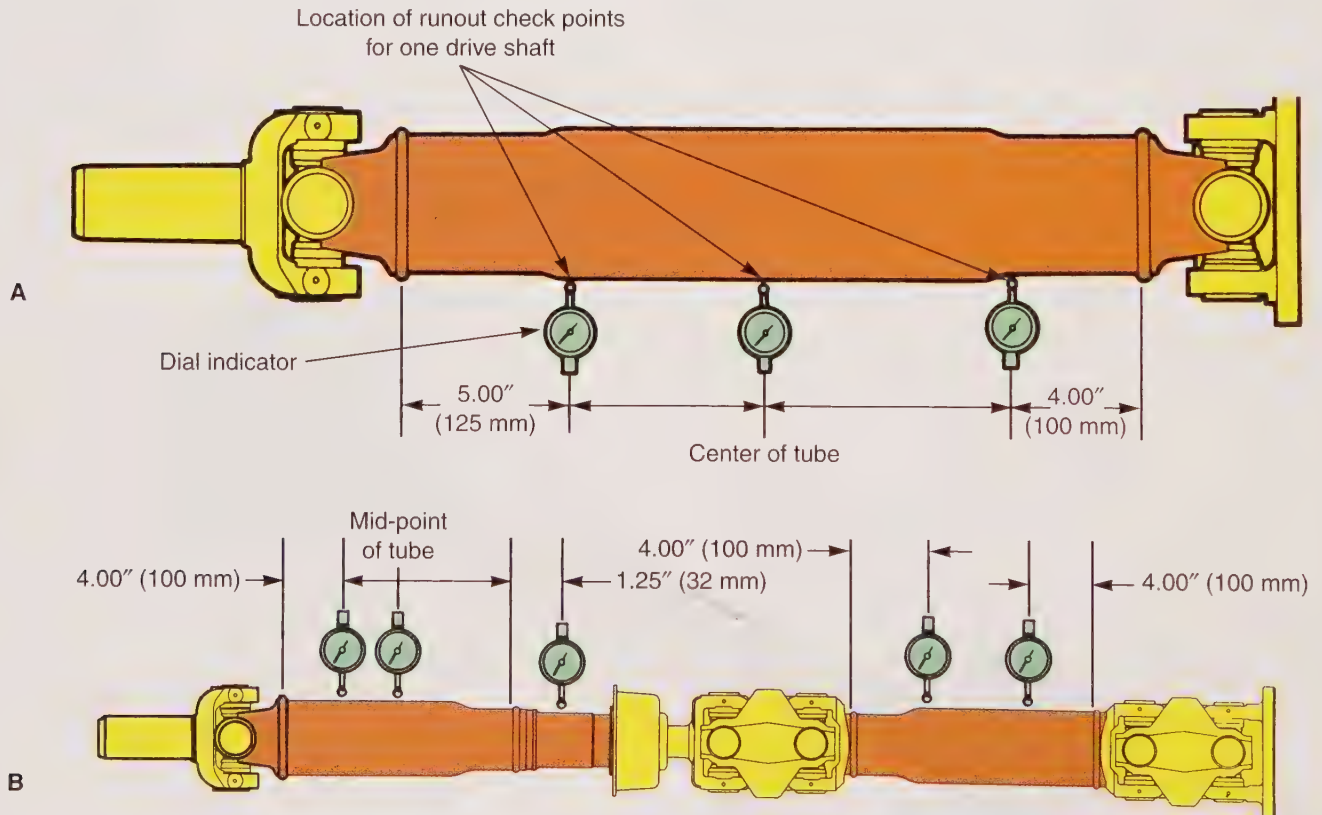


Figure 13-6. This shows the usual locations where the dial indicator is placed to check drive shaft radial runout. Any variation from factory specifications means corrections must be made to the drive shaft. A—Measuring runout on a one-piece drive shaft. B—Measuring runout on a two-piece drive shaft. (General Motors)

Drive shaft angle

Original drive shaft angles can change over time, and they do. Angle changes can be caused by sagging springs at the front or at the rear, and wear and settling of front or of rear suspension bushings. Vehicle modifications can also affect original drive shaft angles. Installation of air shocks and shortening or lengthening the drive shaft in order to use a different transmission are two examples. Further, collision damage can alter the original drive shaft angles of a vehicle.

When drive shaft angles fall out of specification or change so that the two U-joints are not of the same approximate angle, drive shaft vibration is likely to occur. If the inclination of the drive shaft is too great, the U-joints may break on hard acceleration.

Drive shaft angles are set at the factory by the design of the drive train and chassis. They can be changed in the field by adjusting the rear axle assembly or by adding or removing shims between the transmission and the transmission mount.

Before checking drive shaft angles, make sure the rear axle housing is at its curb-height specification (normal position, or ride height) relative to the vehicle body. The wheels do not have to turn freely, but you must have some way to rotate the drive shaft by 90°.

The ideal situation is for the vehicle to be over a pit or on a drive-on platform hoist. You can use another safe way to raise the vehicle, as long as the rear axle housing is in the proper relative position and the vehicle is at its normal weight. The gas tank should be full, and there should be nothing heavy in the car. Before beginning, bounce the vehicle up and down to take any windup out of the springs.

If your vehicle specifications call for checking the distance between the top of the rear axle housing axle tubes and the bottom of the chassis, do so now, before checking the U-joint angles. If the distance is too much, you may have to add some weight to the vehicle to obtain the proper readings. If the distance is too short, the springs are sagging and should be replaced.

Clean off any dirt, undercoating, and rust from all of the U-joint bearing cups. This will help ensure an accurate measurement. Then, take the angle readings.

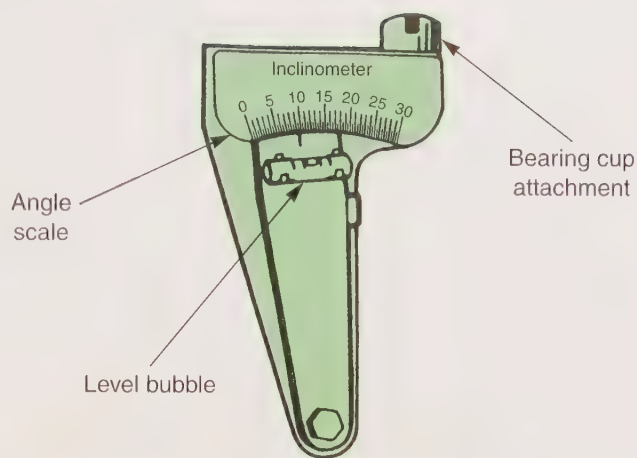


Figure 13-7. The inclinometer is a tool used to determine drive shaft angles. The inclinometer shown is a typical model recommended by many vehicle manufacturers. (General Motors)

Checking drive shaft angles requires a measuring tool called an **inclinometer**. See **Figure 13-7**. This tool measures inclinations of drive train parts, relative to a horizontal reference plane. The readings are then used to calculate the difference between inclinations of two mating parts. This difference is the U-joint angle. See **Figure 13-8**.

Begin by placing the inclinometer on the bearing cup at the drive shaft rear yoke. Make sure the bearing cup is facing downward (pointing straight up and down). Next, using a gauge with a level bubble, center the bubble in the sight glass and record the measurement.

The next step is to rotate the drive shaft 90° and place the gauge on the bearing cup at the differential pinion yoke/flange. Center the bubble in the sight glass and record the measurement. Subtract the smaller reading from the larger reading if the slopes of the two connected components run in the same direction. If the slopes run in opposite directions, add the readings. The answer is the rear U-joint angle.

After obtaining the rear U-joint angle, measure the front U-joint. Start by placing the inclinometer on the bearing cup at the drive shaft front yoke. Make sure the bearing cup is

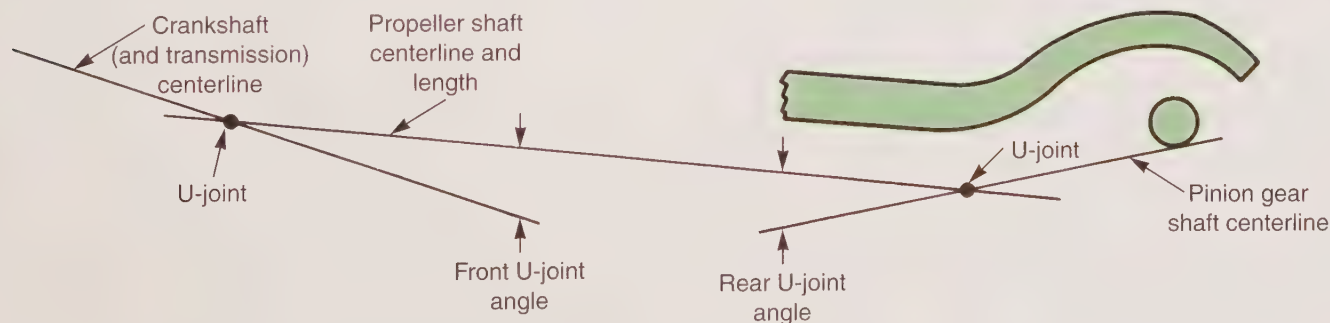


Figure 13-8. U-joint angles of a typical drive train are shown here. Inclinations of transmission output shaft, propeller shaft, and drive pinion gear shaft, obtained through the use of an inclinometer, are needed to determine U-joint angles. U-joint angles are the angles between the centerlines of these components. They may be determined by adding or subtracting inclination readings, as required. (Chrysler)

straight up and down. Center the bubble in the sight glass and record the measurement.

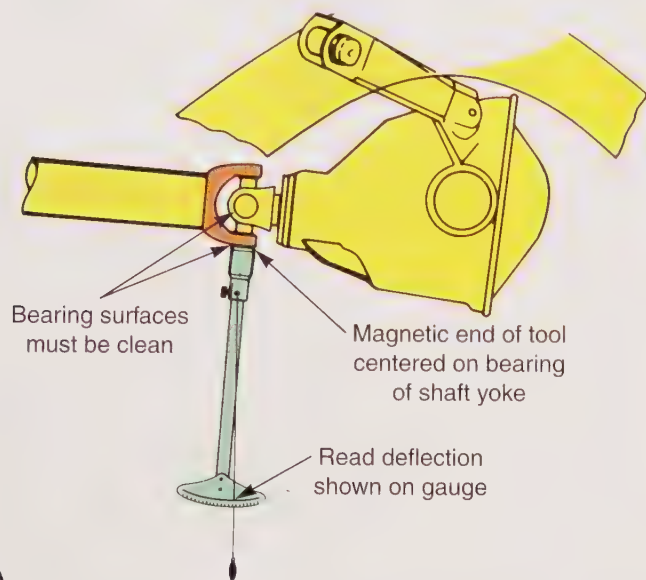
Then, rotate the drive shaft 90° and place the gauge on the bearing cup at the slip yoke. Center the bubble in the sight glass and record the measurement. Subtract the smaller figure from the larger figure, or add the two figures, as required. This will give you the front U-joint angle.

Note that with certain inclinometers, like the one shown in **Figure 13-9**, the U-joint angle may be read directly from the

inclinometer. Unlike the inclinometer shown in Figure 13-7, this inclinometer has an adjusting knob for zeroing the gauge.

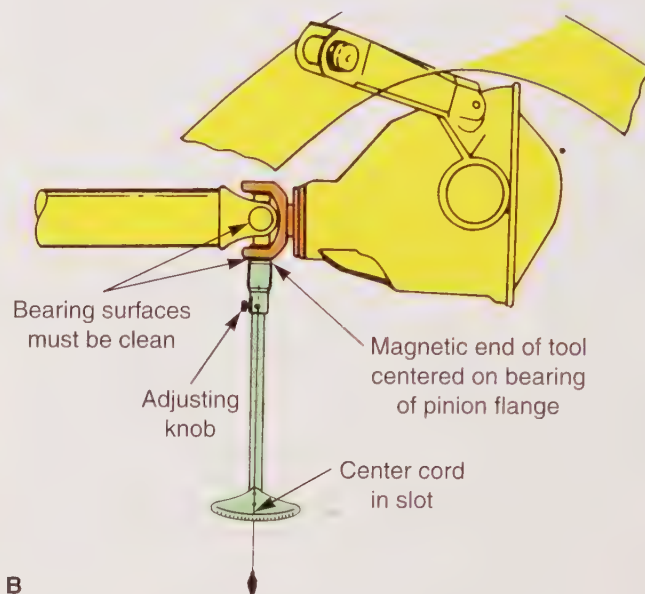
In-Car Drive Shaft Assembly Service

If a vehicle is experiencing drive shaft assembly problems, certain adjustments can be made with the drive shaft



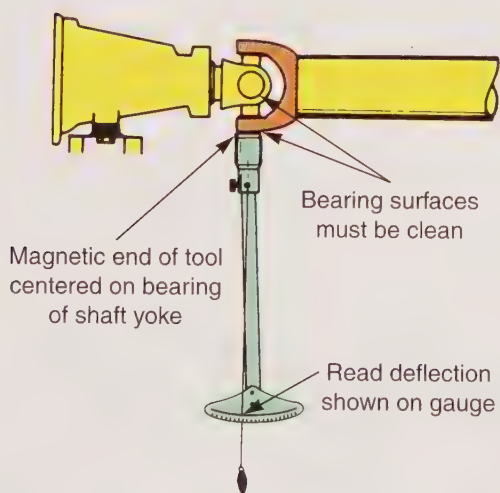
A

A — This checks the drive shaft inclination by attaching an inclinometer at the drive shaft rear yoke. With the gauge having been zeroed, the rear U-joint angle is read directly off the scale.



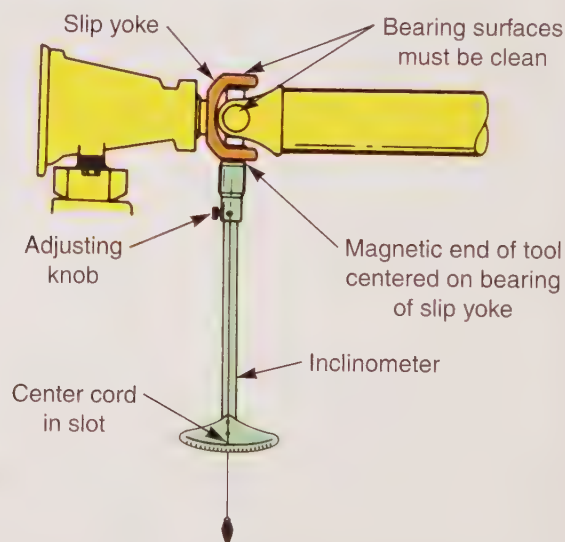
B

B — This checks the inclination of the drive pinion gear shaft by attaching an inclinometer at the pinion flange. The adjusting knob is turned to zero the gauge.



C

C — This checks the drive shaft inclination by attaching an inclinometer at the drive shaft front yoke. With the gauge having been zeroed, the front U-joint angle is read directly off the scale.



D

D — This checks the transmission inclination by attaching an inclinometer at the slip yoke. The gauge is zeroed by turning the adjusting knob.

Figure 13-9. This shows the places where drive train inclinations are measured. This type of inclinometer has an adjusting knob for zeroing the gauge, permitting the direct reading of the U-joint angles. Other inclinometers do not have this feature, and the U-joint angles must be calculated from the readings. The gauge manufacturer and service manual should always be consulted to check U-joint angles. (General Motors)

assembly installed that might correct the problem. It may be that a drive shaft angle is too severe or that the drive shaft is out of balance. Either problem can sometimes be fixed by adjusting the angle or balancing the shaft. Of course, it could be that the drive shaft assembly components simply need to be greased. In-car service procedures are detailed in this section.

Adjusting Drive Shaft Angles

After measuring both front and rear U-joint angles, you can compare the two against specifications. If the U-joint angles are less than the maximum allowable angles, no adjustment is necessary. However, if the U-joint angles are greater than the maximum allowable angles, they must be adjusted.

One way to adjust drive shaft angles is to add or remove shims from the transmission mount. A **shim** is a thin sheet of metal that is placed between two surfaces to keep them apart. Generally, adding shims at the transmission mount reduces the angle of the front U-joint, while increasing the angle of the rear U-joint. Removing shims has the reverse effect. The front U-joint angle changes about twice as much as the rear U-joint angle. This makes transmission mount shimming an effective adjustment when the front U-joint requires the most correction.

Sometimes, the control arms attaching the rear axle assembly to the vehicle chassis can be loosened and the rear axle assembly moved up or down to adjust the rear U-joint. This movement is limited, however, and may have to be done in combination with transmission mount shimming to get the proper angle. If the vehicle has rear leaf springs, the rear U-joint angle is sometimes adjusted by placing wedges between the top of the spring leaves and the bottom of the rear axle housing.

A final adjustment, when all else fails, is to change the front engine mounts. The original mounts gradually compress and may cause drive shaft angles to fall out of specifications. New mounts will usually restore the original engine and transmission height and correct angle changes. Shimming the front engine mounts is impractical and often causes mount or fastener failure.

Balancing a Drive Shaft

Balance in a rotating part is achieved when all forces cancel each other out. A balanced drive shaft has weight distributed equally around its centerline. The only way a drive shaft can typically lose its original factory balance is if a balance weight gets thrown off, the shaft gets badly dented, or undercoating gets sprayed on the shaft. Drive shafts seldom go out of balance. When they do, they can usually be rebalanced by either mechanical or electronic means using standard screw-type hose clamps.

In preparation, the vehicle should be raised on a hoist with the rear axle housing supported and the wheels free to rotate. See **Figure 13-10**. After raising the vehicle, check

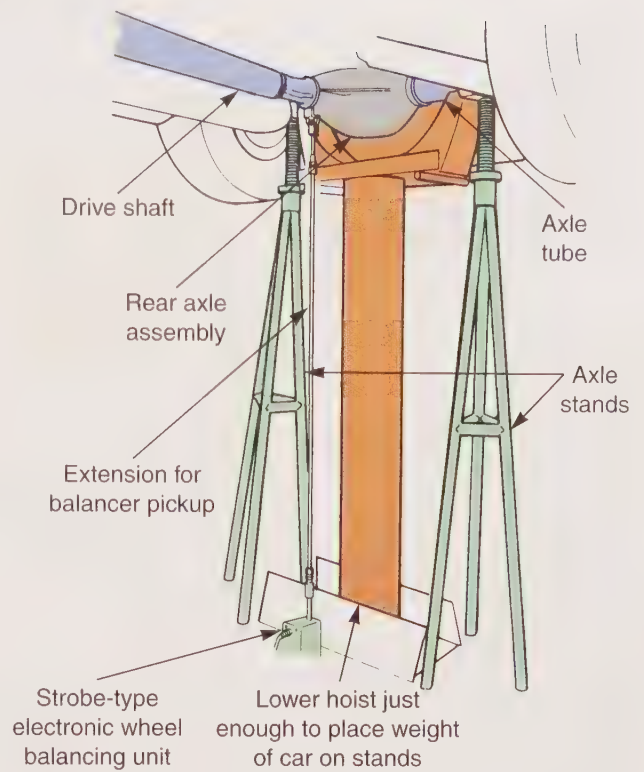


Figure 13-10. Before balancing the drive shaft, raise the vehicle on a hoist. The rear axle housing must be supported, and the rear wheels must be free to rotate. For electronic balancing, support the axle tubes with axle stands, lowering twin-post hoist (shown here) so that it just clears the axle. This way, sensitivity of operation is not destroyed. (General Motors)

the U-joints for wear and check the drive shaft for extreme bends or dents.

If the U-joints and the drive shaft do not show any damage, remove both rear wheels. This way the balance or imbalance of the wheels will not affect rotation of the drive shaft. Reinstall the wheel lug nuts with the flat sides inward. This will hold the brake drums or discs in place.

Next, mark and number the drive shaft at four spots, 90° apart. Make the marks at the rear of the shaft ahead of any balance weight, as shown in **Figure 13-11**. Then, start the engine and shift the transmission into Drive. Run the vehicle at approximately 55 mph (89 km/h), noting the amount of vibration. Turn off the engine.



Warning: Use extreme caution when working around a spinning drive shaft. Do not let any part of your body come in contact with the drive shaft. Watch that your hair does not get caught in a U-joint.

Install two hose clamps near the rear of the propeller shaft, **Figure 13-12**. Align the screws of both clamps at one of the four marks that you made on the shaft. Tighten the clamps securely. Make sure the clamps will not hit any stationary part of the vehicle when the drive shaft is

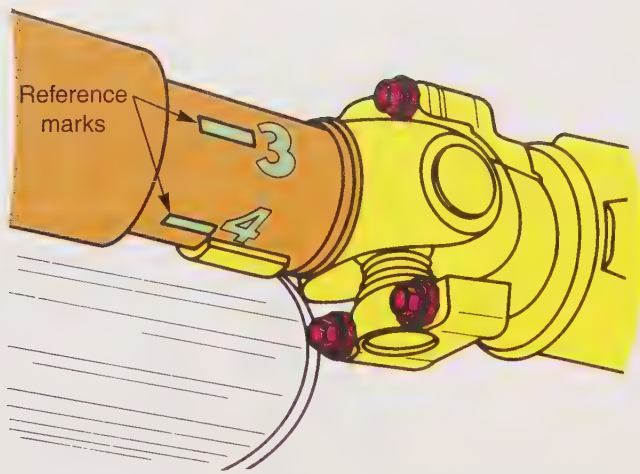


Figure 13-11. This shows the way to make preliminary reference marks on a drive shaft for balance checking. The vehicle is then run at a specified speed with the rear wheels off the ground. The amount of vibration is noted. (General Motors)

rotating. Again, start the engine and shift the transmission into Drive. Run the vehicle at approximately 55 mph and note the amount of vibration.



Caution: To avoid overheating the transmission or engine, do not operate the vehicle on the hoist for long periods of time.

Press on the brake pedal to stop drive shaft rotation. Then, shift into Park and turn off the engine. Rotate the clamps to the next mark on the drive shaft. Again, run the engine to 55 mph and note the amount of vibration. Repeat this procedure until the vehicle has been tested with the clamps at all four spots on the shaft.

Decide which point produced the least vibration and reposition the clamps at that point. Next, rotate the clamps

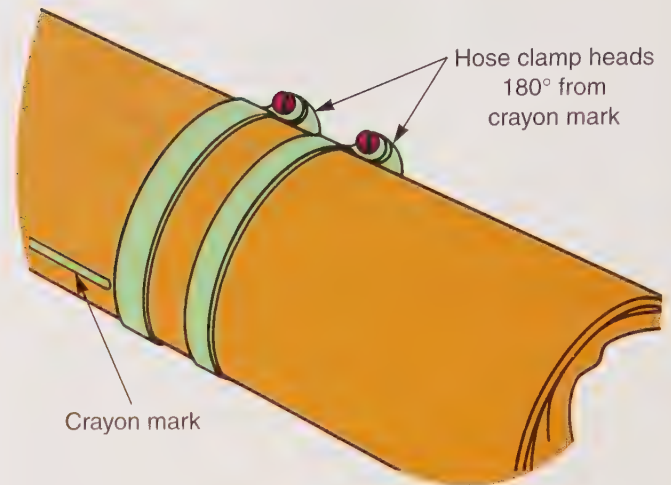


Figure 13-12. Hose clamps are installed on the drive shaft to check balance. The vehicle is then rechecked for greater or lesser vibration at the same speed, with the wheels still off the ground. (General Motors)

away from each other about 45°—one clamp rotated each way from the point of minimum imbalance. This is shown in **Figure 13-13**. Run the vehicle again and note if the vibration has been reduced. Continue to move the clamps away from each other in smaller amounts until the vibration is at its minimum.

In some cases, it may be necessary to use just one clamp at the point of minimum imbalance. In other cases, to obtain a good balance, it may be necessary to use three clamps, with the third clamp between the two outside clamps. If three hose clamps do not solve the problem, replace the drive shaft or have it rebuilt (a new shaft installed between yokes).

Reinstall the wheels and road test the vehicle. Often, a slight vibration felt with the vehicle on a hoist may not be detectable with the vehicle on the ground.

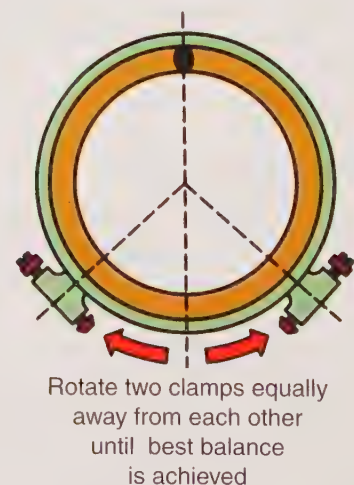
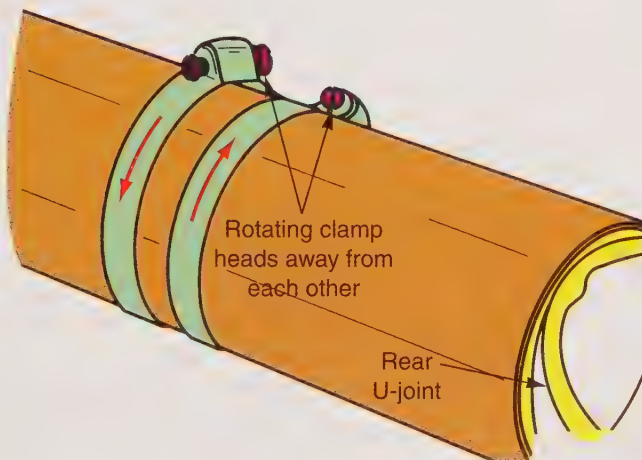


Figure 13-13. This shows the next step in drive shaft balancing. Hose clamps are rotated and the vehicle is rechecked to obtain the location of the least vibration. If the vibration cannot be reduced beyond a reasonable amount, the drive shaft tube must usually be replaced. (General Motors)

Greasing the Drive Shaft Assembly

Modern drive shaft assemblies seldom need any type of maintenance except for periodic greasing. Drive shaft assembly parts that have grease fittings should be lubricated periodically. This applies to some U-joints, slip yokes, and center support bearings. Although these drive shaft assembly parts do not move great distances, they are under heavy pressures during vehicle operation and require good lubrication.

Since the drive shaft assembly parts are under the vehicle, they are exposed to dirt and water from the road. These elements cause rapid wear and rusting. Grease and good sealing prevents the entry of dirt and water, lengthening the service life of drive shaft assembly parts.

A good rule is to grease all drive shaft assembly fittings whenever the front end is greased. Remember, most original equipment U-joints do not have grease fittings.

U-joint greasing is a simple procedure, requiring the same grease gun used for front-end lubrication. U-joint grease fittings, often called Alemite, or Zerk, fittings, are identical to those used on front-end parts. The greasing procedure is simple:

1. Wipe off the grease fitting with a rag.
2. Install the grease-gun nozzle over the grease fitting.
3. Pump in grease until the bearing cup seals swell slightly.
4. Remove the grease-gun nozzle and wipe off excess grease.

Some fittings require special adapters. In other cases, the grease is injected through a hole by a special grease nozzle. The greasing procedure is the same as for standard grease fittings. If the fittings have dust caps or seals, these should be put back after greasing is completed.

Do *not* overgrease the U-joint. Pumping in grease until it flows out of the seals can destroy the seals. Water and dirt can then quickly enter the U-joint and destroy it.

Slip yokes and center support bearings that have grease fittings are greased in the same manner as U-joints. The same precautions against overgreasing should be observed.

Drive Shaft Assembly Removal

Inspection of the installed drive shaft assembly may have been enough to pinpoint the cause of a particular problem a vehicle is experiencing. On the other hand, your inspection efforts may have proven inconclusive; in which case, further inspection is required. In either event, the drive shaft assembly will have to be removed. The drive shaft assembly must also be removed before the transmission can be removed or before making repairs to the rear axle assembly.

It is easy to remove a drive shaft assembly. The following removal steps apply to Hotchkiss-type drive shafts.

Consult the proper service information to remove a torque-tube drive shaft.

1. Place the vehicle transmission in Neutral.
2. Raise the vehicle in a safe manner.
3. Place match marks at the rear of the drive shaft and differential pinion yoke or flanges. This will guarantee that the drive shaft assembly will be reinstalled in its original position. Balance will not be affected if the assembly is installed in the same position.
4. If the drive shaft has a center support bearing, remove the bracket and save the attaching hardware. In rare cases, the center support is inside the frame.
5. Remove the fasteners that hold the rear of the drive shaft assembly to the rear axle assembly. This may mean unbolting and separating a companion flange, as in **Figure 13-14**, or it may mean removing two U-bolts secured with nuts or two straps secured with cap screws. If a CV joint is used, it is probably attached to a companion flange with four cap screws.



Note: Do not let loose bearing cups fall off their trunnions once U-bolts or straps are removed. The cups can be held in place with masking tape or a large rubber band if they are very loose. This will keep the needle bearings from spilling out.

6. Lower the rear of the drive shaft assembly until it is below the pinion yoke or flange. For drive shafts that were fastened with U-bolts or straps, slide the drive shaft assembly forward until the rear U-joint clears the differential pinion yoke. The slip yoke will slide about 1" (25 mm) into the transmission. If the U-joint sticks to the pinion yoke, it can be lightly pried loose with a large screwdriver. Do not forget to hold the drive shaft while doing this.

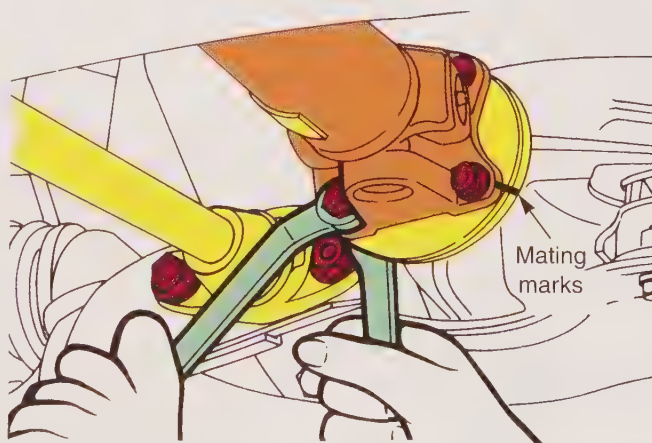


Figure 13-14. This shows the drive shaft assembly being detached at the rear axle assembly. Note how the mating flanges are marked before the rear of drive shaft assembly is unbolted. (Chrysler)



Caution: Do *not* let the full weight of the drive shaft hang on the slip yoke. Support the assembly to prevent damage to the extension housing and bushing and the front U-joint.

7. Pull the drive shaft assembly out of the transmission. Some oil may drip out of the rear of the transmission when the assembly is removed, so have a container ready. Drips can be prevented by placing a plastic plug or an old slip yoke in the rear of the transmission or by slightly lowering the front of the vehicle.

Cross-and-Roller U-Joint Service

Once the drive shaft assembly is removed, you can disassemble it. Prior to disassembly, bench check the U-joints, and after disassembly, you can further inspect them, if necessary, to pinpoint the cause of a particular problem. If a U-joint is defective, you must install a replacement.

U-Joint Disassembly

Prior to disassembly, quickly bench check the U-joints. Checking a U-joint on the bench is similar to checking it on the vehicle, **Figure 13-15**. The major advantage to bench checking is that the joint can be more closely inspected. It allows for bending the joints at angles greater than possible when the drive shaft is on the vehicle. The joints can be closely inspected for excessive play. Move the yokes and U-joints to the limits of their travel and note any roughness, noise, or binding. After you have assessed the joint action, you are ready to remove the U-joints from their installation.

Before trying to remove the U-joints, place the drive shaft assembly on a stand or bench so that the drive shaft is horizontal. The drive shaft yoke can be placed in a vise to keep it from slipping off the bench. Be careful not to clamp it too tightly!

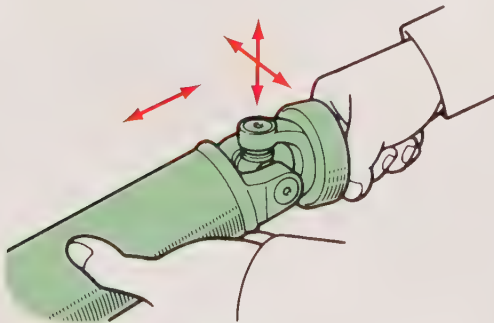


Figure 13-15. Note how to bench check a U-joint for wear. Pull on and wiggle the parts attached to the U-joints, as shown, while watching for movement. Also, rotate the parts on their trunnions. (Toyota)

Start by putting on your safety glasses and removing the retainer snap rings or clips for the bearing cups. The U-joints may have internal metal clips that fit over a shoulder in the bearing cup. Alternately, they may have clips that fit into a groove on the outside of the yoke. Use screwdrivers, snap ring pliers, or needle-nose pliers to remove them.

A few original equipment U-joints use injected plastic to hold the cups in the yokes. The plastic can be melted with a torch just before removing the cups. Replacements for U-joints with injected plastic retainers use internal metal clips to secure the cups.

Bearing cups of large trucks and some cars may be held with U-bolts, straps, or covers. These can be removed by unscrewing the fasteners.

Note that if you are removing a front U-joint or any U-joint between two shafts, you *must* scribe match marks on the neighboring parts. For instance, mark the slip yoke and the front part of the drive shaft. This is so they can be reassembled in the same position relative to each other.

Next, obtain two sockets from a socket wrench set. One should have an inside diameter that is slightly larger than the bearing cup. This socket will act as a receiver for the bearing cup. The other should have an outside diameter that is slightly smaller than that of the bearing cup. This socket will act as a bearing cup driver. Note that special bearing removal sleeves or two short segments of pipe can be used instead of the sockets.

Position the sockets in a press of some sort to drive the bearing cups out of their yokes. The driving can be done with several different types of tools:

- ❑ A vise, as in **Figure 13-16**.
- ❑ A C-clamp or a C-frame driver, as in **Figure 13-17**.
- ❑ An arbor press, as in **Figure 13-18**.

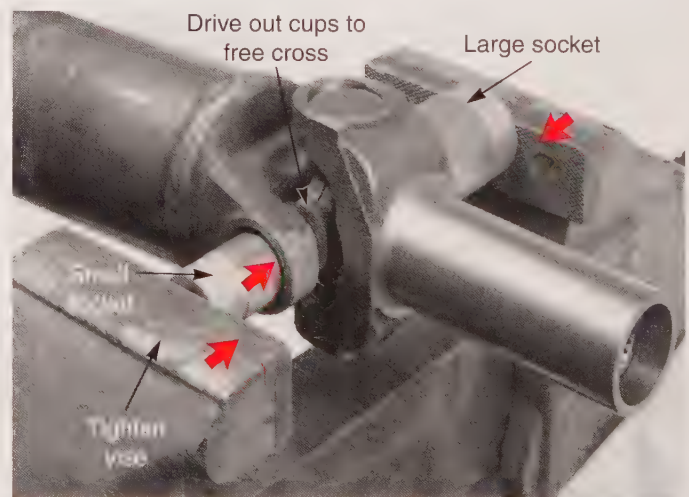


Figure 13-16. A vise and two sockets can be used to remove bearing cups and U-joints. Place the socket as shown, and slowly tighten the vise. A small socket presses the bearing cup on the opposite side out of the yoke and into the large socket. If the cup fails to come out completely, clamp it in a vise just until it is snug, and tap the yoke from the underside with a plastic mallet. Remove the other bearing cup by repeating the entire procedure. Then, remove the cross. (Chrysler)

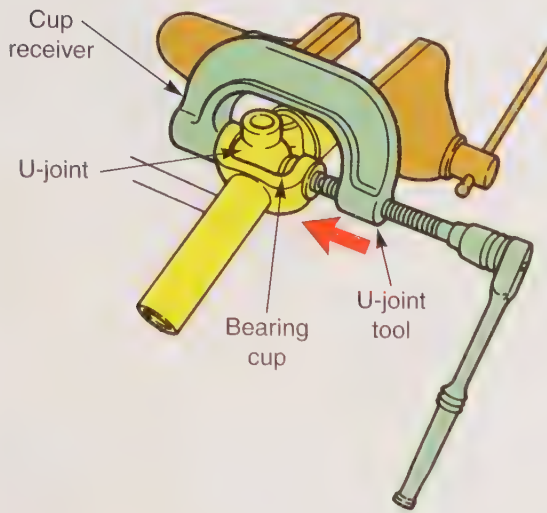


Figure 13-17. This special service tool, resembling a C-clamp, is used to remove a bearing cup and cross. Turning a screw on the U-joint tool drives the bearing cup on the opposite side out of the yoke and into the cup receiver. This special tool is self-contained, eliminating the need for sockets. Note that a C-clamp and two sockets could be used in its place. (Ford)

Alternately, a hammer and driver can be used to drive bearing cups from their yokes, as in **Figure 13-19**. It is helpful to place a socket on the bench to receive the bearing cup, placing one of the yoke lugs against the socket. Place the driver over the opposite bearing cup. Carefully strike the driver with a hammer until the cross moves down and forces the bottom bearing cup out of the yoke.



Warning: Do *not* use a socket as a driver when hammering. The socket may shatter when struck with a hammer.

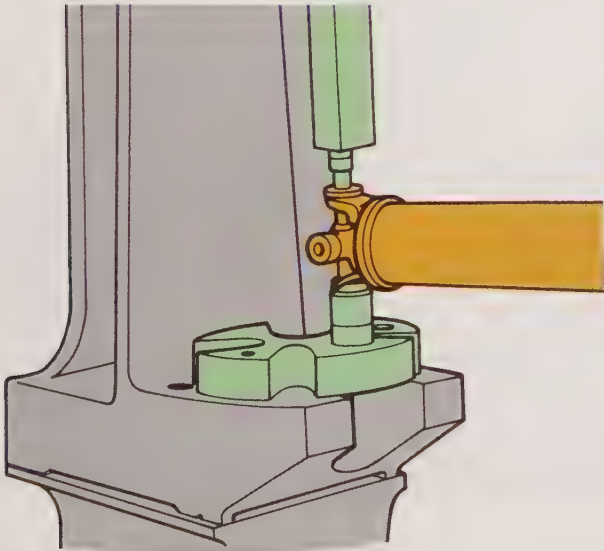


Figure 13-18. This shows an arbor press being used to remove a bearing cup from a yoke. (General Motors)

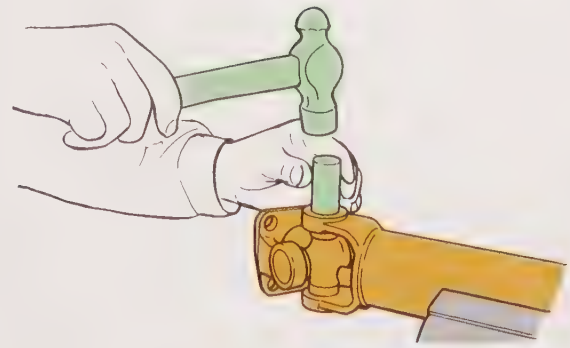


Figure 13-19. The bearing cups and the U-joint cross are removed with a hammer, a driver, and a vise (used to hold the drive shaft). This procedure should always be done carefully, since the chance of damage or personal injury is great. Always wear eye protection when using a hammer on a U-joint, and never take a hammer to a socket. (General Motors)

Repeat the removal process on the opposite bearing cup. If the cup does not come completely out, you can remove the cross from its yoke and, then, use a brass drift to force out the bearing cup. Repeat this operation on the other yokes as needed.

U-Joint Inspection

Normally, a U-joint is replaced anytime it is disassembled. If the joint is relatively new, however, you can inspect, clean, lubricate, and reassemble it.

Inspect the U-joint for wear or rust and clean the roller bearings and other parts in solvent. The U-joint trunnions should be perfectly smooth and round. There should be no signs of cracking, spalling, or pitting. If there is any sign of such wear or damage anywhere on the U-joint cross, the U-joint should be replaced. If rust powder is found in any U-joint bearing cup, replace the U-joint. It makes no sense to go to the trouble to remove and disassemble a U-joint and, then, reinstall a defective joint.

While the drive shaft assembly is disassembled, check the other drive shaft parts for wear, rusting, or damage. Make sure the yokes do not have any burrs caused by removing the bearing cups. Burrs should be removed with a file or sandpaper.

It is easier to check for a bent drive shaft when the drive shaft is in the vehicle. It can, however, be done with the shaft removed by placing it between two V-blocks and checking with a dial indicator. Check in the same places as on an installed drive shaft. If the drive shaft appears to be bent, send it to a drive shaft specialty shop for tube replacement.

U-Joint Installation

New U-joints come pregreased. They do not require additional greasing until some time after they are installed. You will need to use grease, however, to retain bearing needles if they have been removed from a bearing cup. If

you are sure a used U-joint can be reused, add some grease to each bearing cup after cleaning and before installation.

If a U-joint disassembled for inspection is found to be usable, begin bearing cup installation by lining the cup with the U-joint needle bearings. To prevent the needles from falling out, always handle the bearing cups gently and use grease to hold the needles in place. Install new seals on each cup and make a final check just before installing the cups onto their trunnions.

Note that the major difficulty when installing a U-joint is having bearing needles fall out of position. They fall to the bottom of the cup and prevent the bearings from fully seating. If this happens, the retainer snap rings or clips will not fit into their grooves, and you will have to disassemble the U-joint and start again.

To install a bearing cup onto its trunnion, push the cup about a quarter of its length into either lug of the front yoke. See **Figure 13-20**. Push carefully by hand and check for proper alignment. Make sure the bearing needles are still in place. Then, position the U-joint cross in the front yoke and into the bearing cup. Hammer or press the cup onto the trunnion until the bearing cup is flush with the outside of the yoke and fully seated on the cross trunnion. See **Figure 13-21** and **Figure 13-22**.



Caution: If the bearing cup fails to press into place with normal pressure, take apart the joint and check the needle bearings. A needle may have fallen over in the cup. If left uncorrected, the U-joints and drive shaft could be ruined.

Install another bearing cup into the yoke lug opposite the one just worked on, making sure the bearing needles do not jam on the trunnion. Hammer or press the cup onto its trunnion.

Install the retainer snap rings or clips now to ensure the bearing cups are fully seated. See **Figure 13-23**. Afterward, make sure the U-joint can move freely. If the

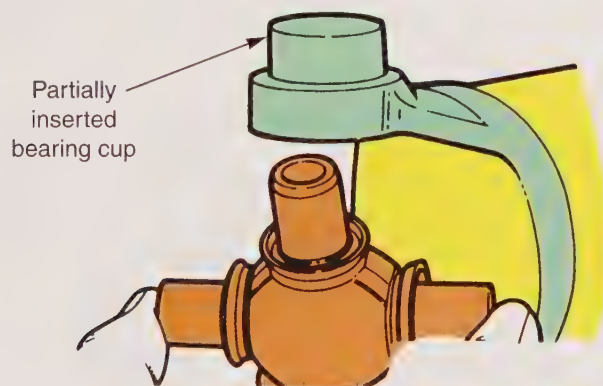


Figure 13-20. Once the bearing cup is partially inserted, it should be checked to ensure the needle bearings have not fallen out of place. Then, the cross should be installed and the bearing pressed into place on the trunnion. (General Motors)



Figure 13-21. Drive the cup over the trunnion without disturbing the needle bearings. Make sure the cup installs fully. If you have to use excess force, a needle has probably dropped down. Disassemble and start over. (Chrysler)

U-joint is jammed, it can usually be freed by lightly tapping it with a hammer.

Install the rest of the bearings in the same manner, making sure to align the marks you made during disassembly. Check rotation, as before, to make sure the U-joint moves freely. Bearing cups of rear U-joints held by straps or U-bolts may be placed on their trunnions and secured with tape until the drive shaft assembly is reinstalled. If a new

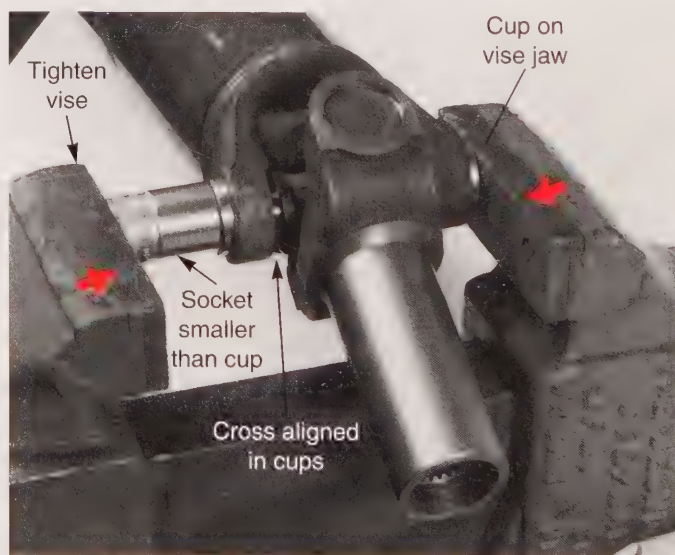


Figure 13-22. A vise and one small socket can be used to press the bearing cups into the yoke. Press the cup in until you can install one snap ring. Then, press the other cup in and install the other snap ring. (Chrysler)

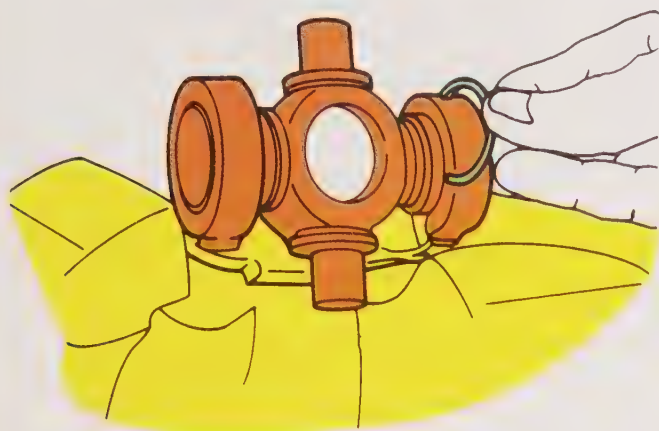


Figure 13-23. Fit retainer clips or snap rings back into their grooves. (General Motors)

U-joint has a grease fitting, add a small amount of grease to displace any air inside the cross assembly.



Caution: Do *not* overgrease, as this will destroy the U-joint seals.



Note: Some center support bearings are a slip fit and a press is not needed.

As you remove the center support, make note of the position of all spacers, washers, and seal protectors so they can be reinstalled in the same position as they were on the original bearing. Inspect the new bearing to ensure it matches the old bearing. Some bearings have a mark that indicates the direction in which they should be installed, **Figure 13-24**. Press the new center support bearing into place until it bottoms on the drive shaft. Once the new bearing is in place, reassemble the drive shaft and reinstall it on the vehicle as explained in the next section of this chapter. On some vehicles, the nut holding the center support to the drive shaft must be staked to keep it from loosening. See **Figure 13-25**.

Double Cardan U-Joint Service

A double Cardan U-joint is serviced using the same general procedures just discussed. However, you must mark more parts to ensure alignment upon reassembly.

If the centering ball is worn, it can be replaced without replacing the center yoke. After replacement, lubricate the ball and socket with chassis grease. Once this is done, the CV joint is reassembled by engaging the ball and socket and aligning any reference marks. On many of these CV joints, you will need to install the U-joint bearing cups while holding the spring-loaded ball-and-socket assembly together. This is the only way to make sure the yokes and bearings are properly aligned.

Center Support Bearing Service

Most center support bearings are sealed and cannot be lubricated. Loose or noisy support bearings are replaced. Some center support bearings are removed by removing the center support and the front and rear drive shafts as a unit. On other vehicles, the slip yoke is installed between the front and rear drive shaft. If this design is used, the front drive shaft must be removed first. Then the center support and rear drive shaft can be removed together. Even if the front drive shaft does not have to be removed to remove the center support, it is often easier to remove it now rather than on the bench. If there is any possibility of reinstalling the drive shaft parts in a different position, make match marks on all mating parts.

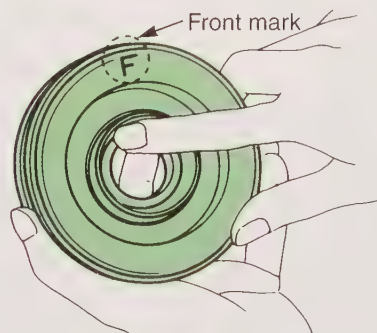


Figure 13-24. Some center support bearings have an F or other mark to indicate their direction of installation. Always make sure that center support bearings are installed facing the proper direction. (Nissan)

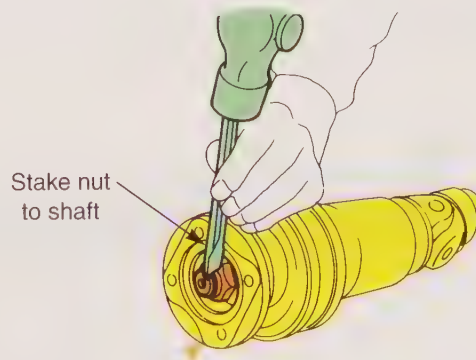


Figure 13-25. If required, stake the center support drive shaft-attaching nut to ensure that it does not loosen with use. (Nissan)

Drive Shaft Assembly Installation

Before installing the drive shaft assembly, check all of your repairs. Also, check the condition of the extension bushing and rear seal. Lightly oil the outside of the slip yoke with the proper type of transmission fluid. Double-check your alignment marks on the drive shaft and slip yoke (if previously disassembled). Having made these preliminary checks, follow the appropriate drive shaft assembly installation procedures.

To install a one-piece drive shaft:

1. Slide the slip yoke onto the transmission output shaft. Be careful not to damage the rear seal.
2. Position the rear U-joint on the differential pinion yoke or position the companion flanges, as applicable. Make sure you line up the marks you made during removal.
3. Tighten fasteners, installing U-bolts or straps as applicable. Ensure that the bearing cups align properly in the pinion yoke. Be careful not to overtighten the fasteners and break them.
4. Lower the vehicle and perform a road test.

To install a two-piece drive shaft:

1. Install the rear drive shaft and center support bearing on the vehicle.
2. Loosely install the rear drive shaft and center support bearings fasteners.
3. Install the front drive shaft. Be sure to align the front and rear drive shaft yokes as shown in **Figure 13-26**. This is sometimes called phasing the drive shaft. Some yokes have a larger spline that matches a missing spline in the shaft. This prevents improper phasing.



Warning! If the yokes are not aligned, the drive shaft will vibrate severely.

4. Once all drive shaft parts are installed, tighten the fasteners to the proper torque and check drive shaft alignment.
5. Lower the vehicle and perform a road test.

Summary

Drive shafts are durable and do not ordinarily need much service. However, other drive shaft assembly parts, such as U-joints and center support bearings, often wear out and require replacement. A defective U-joint should be replaced as soon as it is discovered. If it is not replaced, the drive shaft can fall off, causing severe damage and even an accident.

The two major types of drive shaft assembly problems are noises and vibration. Noises can usually be traced to the offending part without much trouble. Drive shaft vibrations are often difficult to isolate and may be confused with other sources of vibration. The drive shaft can vibrate because of a worn or loose U-joint or center support bearing. Vibration can also be caused by a bent or out-of-balance drive shaft, excessive U-joint angles, or a worn out slip yoke or extension bushing.

Precautions are necessary to prevent damage to the drive shaft or personal injury. Always clamp the drive shaft securely but without denting it. Wear eye protection. If any shafts are being separated, mark them so they can be reinstalled in the same relative position.

U-joints can be checked by attempting to rotate the drive shaft back and forth while watching the yokes. Look for excessive movement or play between the cross and bearing cups. Then, move the two yokes up and down and from side to side. Again, any excessive movement means the U-joint is bad.

Once the U-joints have been inspected, check for problems with the other drive shaft assembly parts, such as the slip yoke and center support bearing. Also, check the extension bushing.

After performing a visual inspection, you can perform measurement inspections, including checking drive shaft runout and drive shaft angle. The runout check is used to determine whether or not the drive shaft is straight. Drive shaft angle inspection provides a way to check angles through the U-joints.

Adjusting drive shaft angles, balancing a drive shaft, and greasing a drive shaft assembly are all in-car service procedures. These procedures may correct a vehicle's drive shaft assembly problem.

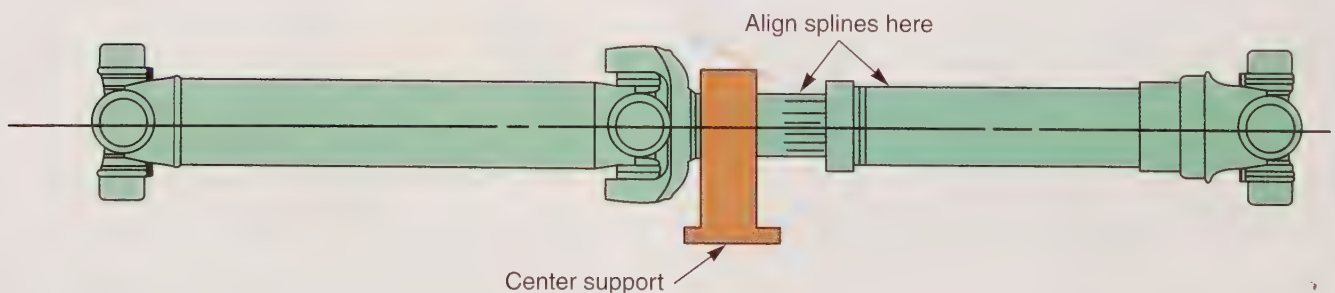


Figure 13-26. A two-piece drive shaft must be properly phased. The drive shaft yokes must be aligned as shown in the illustration or the shaft will vibrate excessively and eventually break the U-joints.

Drive shafts require very little maintenance. All parts with grease fittings should be lubricated when the front end is lubricated. Greasing is a simple operation, using the same type of grease gun used on the front-end parts. Some U-joints, including CV joints, must be lubricated by using a special adapter on the grease gun.

The drive shaft must be removed so that it can be repaired. It also must be removed to repair the transmission, clutch, or rear axle assembly. Removing the drive shaft is a simple procedure. However, care must be taken to ensure the heavy drive shaft assembly does not fall, causing damage or personal injury.

The U-joints are removed by pressing or hammering them out of the drive shaft yokes. This operation requires a socket (or other device) with an inside diameter larger than the bearing cup and another tool with an outside diameter smaller than the bearing cup.

U-joints should be carefully disassembled and inspected if you intend to reuse them. Replace U-joints that show any sign of wear, rusting, or other damage.

When installing new U-joints, make sure that the needle bearings stay in place. Carefully reassemble the U-joints and make sure all bearing cups are fully seated and shafts are reinstalled according to their alignment marks. All retainer clips or snap rings should be seated.

The center support bearing should be replaced when it gets noisy or loose. Most center support bearings must be pressed on and off after the center U-joint connector is removed.

Drive shaft installation is the reverse of removal. Be careful not to damage the transmission rear seal and to tighten all the attaching hardware securely.

Review Questions—Chapter 13

Answer the following questions using the information provided in this chapter.

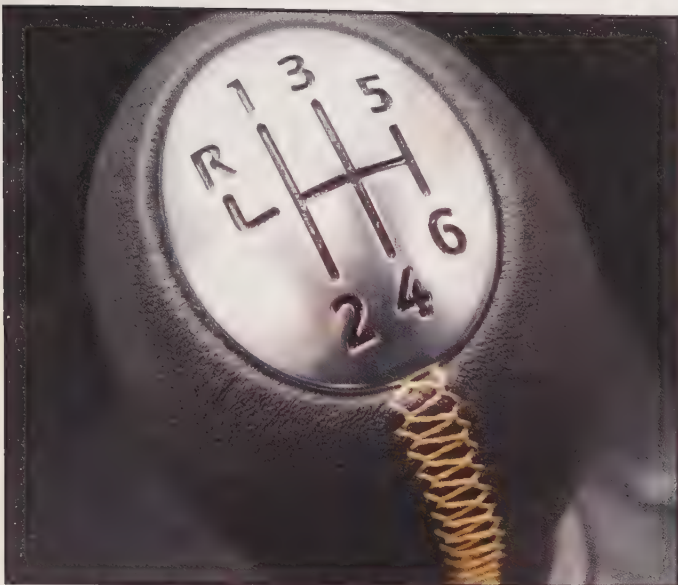
1. Most drive shaft assembly problems are caused by the _____.
 - (A) U-joints
 - (B) CV joints
 - (C) axle shafts
 - (D) drive shafts
2. Squeaks caused by a bad U-joint are usually heard when _____.
 - (A) driving on rough terrain
 - (B) driving in reverse
 - (C) driving in low gear
 - (D) driving on the open road
3. Excessive backlash often shows up in _____.
 - (A) steering
 - (B) suspension
 - (C) drive shaft
 - (D) axle
4. Most drive shaft vibrations are _____.
 - (A) axial
 - (B) radial
 - (C) terminal
 - (D) bilateral

5. If a U-joint shows any sign of looseness, it should be _____.
 - (A) greased
 - (B) cleaned
 - (C) repacked
 - (D) replaced
6. The _____ is used to check drive shaft runout.
7. The _____ is used to check drive shaft angles.
8. Screw-type hose clamps are used to assist with _____.
 - (A) balancing the drive shaft
 - (B) adjusting drive shaft angles
 - (C) universal joint service
 - (D) measuring shaft runout
9. If you pump grease into a U-joint until it flows out of the seals, _____.
 - (A) it is well greased
 - (B) it will fail immediately
 - (C) it might ruin the seals
 - (D) it might ruin the needles
10. If the bearing cup retainers will not seat fully, _____.
 - (A) disassemble the U-joint and locate the cause
 - (B) press the bearing cups together even harder
 - (C) strike the U-joint yokes with a large hammer
 - (D) leave it alone and do not be concerned

ASE-Type Questions—Chapter 13

1. Each of the following statements about drive shaft assembly problems is true *except*:
 - (A) all drive shaft assembly problems are caused by vibration.
 - (B) U-joints are a common source of problems.
 - (C) a bent wheel can be confused with a drive shaft assembly problem.
 - (D) drive shaft assembly malfunctions can result from misaligned parts.
2. Technician A says that a worn U-joint can cause a clunking sound when reversing direction. Technician B says that a loose U-joint can sometimes be repaired by greasing the fitting. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

3. Which of the following is the most likely cause of a squeaking noise coming from the drive shaft assembly?
(A) Bent shaft.
(B) Dry U-joints.
(C) Worn U-joints.
(D) Worn slip yoke.
4. Technician A says that dirt or undercoating on the drive shaft will not affect the smoothness of drive shaft assembly operation. Technician B says that the slip yoke will usually wear much more than the transmission extension bushing. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
5. Each of the following statements about checking drive shaft runout is true *except*:
(A) the drive shaft should theoretically turn in a perfect circle.
(B) the drive shaft should be at a sharp angle during runout checking.
(C) most drive shafts should never require a runout check.
(D) all other drive shaft problems should be eliminated before the runout is checked.
6. Technician A says drive shaft angles can be changed by normal spring wear or by a collision. Technician B says that excessive drive shaft angles can cause broken U-joints. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
7. Original equipment U-joints do not normally have _____.
(A) needle bearings
(B) retainers
(C) grease fittings
(D) a center cross
8. Technician A says that to ensure a drive shaft will not move while removing U-joints, the shaft should be tightly clamped in a vise until it bends slightly. Technician B says that before removing a U-joint between two shafts, the shafts should be marked so they can be reinstalled in the same position. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
9. Each of the following can be used as adapters to remove U-joint bearing cups *except*:
(A) large sockets.
(B) special removal sleeves.
(C) brass drifts.
(D) short pipe segments.
10. A new U-joint is being installed in a drive shaft assembly. The bearing cup cannot be pressed far enough into the yoke to install the retainer snap ring. Technician A says that the problem could be caused by a needle bearing that has fallen to the bottom of the cup. Technician B says that the problem could be caused by a snap ring that is too thick. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.



Chapter 14

Constant-Velocity Axle Construction and Operation

After studying this chapter, you will be able to:

- ☐ Explain the function of a constant-velocity axle.
- ☐ Explain the difference between equal-length and unequal-length drive axle systems.
- ☐ Describe the operation of the different types of constant-velocity U-joints.
- ☐ Describe the construction of a constant-velocity axle shaft.

Technical Terms

Constant-velocity axle

Constant velocity

Unequal-length drive axle system

Torque steer

Intermediate shaft

Equal-length drive axle system

Plunging joint

Ball-and-cage joint

Tripod joint

CV joint boot

CV axle shaft

Central axle shaft

Stub shaft

Wheel bearing

Spindle

Wheel hub and bearing assembly

Bearing support bracket

Wear sleeve

Introduction

This chapter discusses the construction and operation of constant-velocity axles. It explains the operating principles of constant-velocity axle shafts, constant-velocity U-joints, intermediate shafts, and front wheel bearings. Studying this chapter will prepare you for the constant-velocity axle service chapter that follows.

Constant-Velocity Axles

In transaxle-equipped vehicles, the engine and transaxle are bolted together to form an assembly that is mounted at the front or rear of the vehicle. Engine power is transferred from the transaxle to the drive wheels by the **constant-velocity axles**, or **CV axles**. **Figure 14-1** shows a typical front-wheel drive assembly that contains two CV axles. The term **constant velocity** means the axles can transmit power through changing drive angles without variations in axle speed, or rpm. This is necessary because the drive angles of the axles must change as the drive wheels move during vehicle operation. The wheels move up and down as the vehicle travels over uneven road surfaces, and they move to the right or to the left as the vehicle is turned.

The inner, or inboard, ends of the CV axles are connected to the transaxle differential. The axles are driven by the differential side gears. The outer, or outboard, ends of the axles are connected to the wheel hubs. The outer ends are supported and held in alignment by the steering knuckles (front-wheel drive axles) or by the rear bearing supports (rear-wheel drive axles on rear- or mid-engine vehicles or that are independently suspended).

The steering knuckles are heavy mounting attachments for the wheel hubs. They house the wheel bearings and are connected to the front strut assemblies, control arms, and other front suspension parts. The steering knuckles pivot to turn the front wheels. Rear bearing supports house the rear wheel bearings and support the outer ends of the rear drive axles, but usually do not swivel for steering.

CV axles consist of CV joints and CV axle shafts. Some front-wheel drive axles and most drive axles on rear- and mid-engine vehicles are equipped with one or more non-CV flexible joints, or cross-and-roller U-joints, but these are almost always used in combination with CV joints. Undamaged CV axles will operate with little or no vibration.

Figure 14-2 shows a typical CV axle assembly. Although there are many variations to the basic design, most CV axles contain the parts shown here. Note, however, that while most CV axles contain three axle shafts, including a center shaft and two short, or stub, shafts, the CV axle pictured does not have an inner stub shaft.

Equal- and Unequal-Length Drive Axle Systems

In many CV axle systems, the drive axles used on each side of the transaxle are unequal in length. This is because the design of most transaxle installations places the CV axle openings in the transaxle at different distances from their respective wheel hubs. This arrangement is called an **unequal-length drive axle system**, **Figure 14-3A**. The difference in axle length may cause vibrations, because each axle will be turning through a different drive angle.

The difference in drive angles in an unequal-length drive axle system may also cause one wheel to receive more torque during heavy acceleration. This produces an

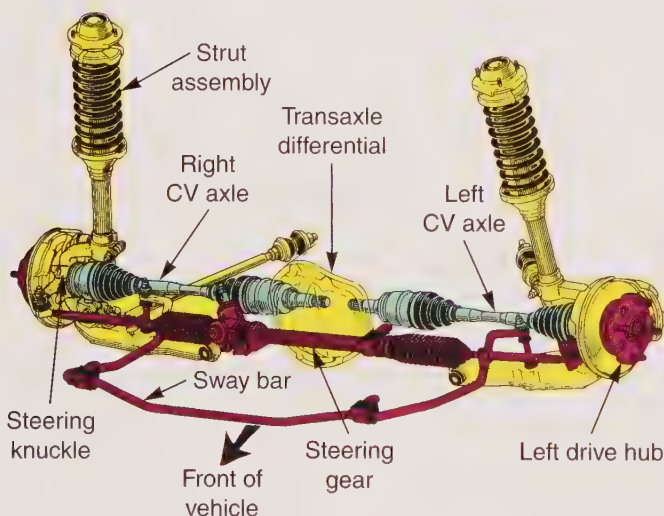


Figure 14-1. In this front-wheel drive assembly, the constant-velocity axles transfer power from the transaxle to the front wheels. (Toyota)

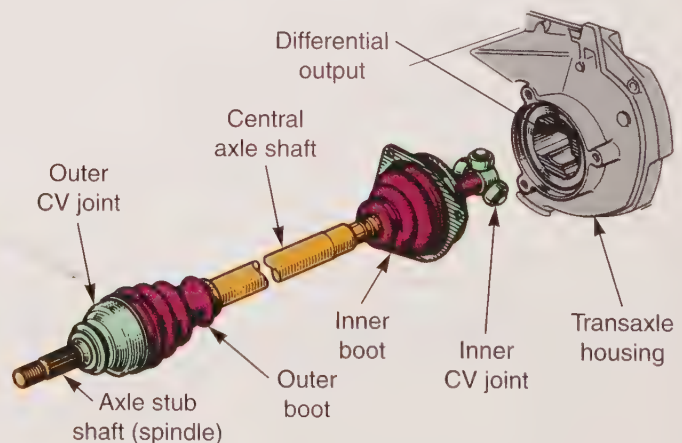


Figure 14-2. This is a typical constant-velocity axle. Notice the central axle shaft, the CV joints, and the boots. Note that this axle does not have an inner stub shaft. The inner joint fits into the transaxle housing.

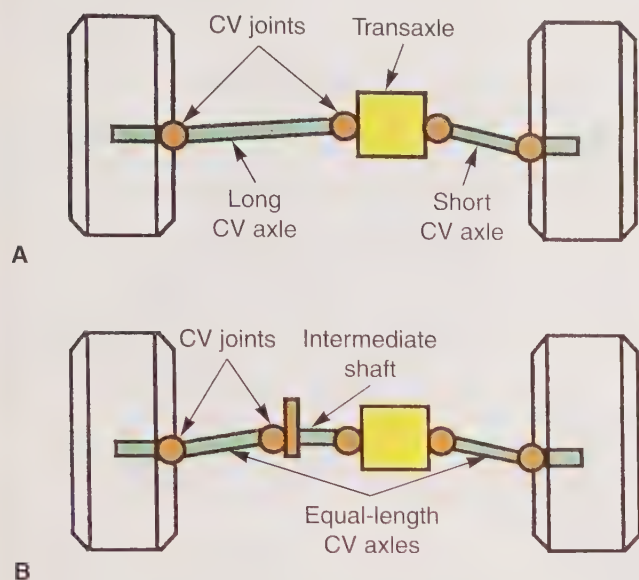


Figure 14-3. Note the differences between equal- and unequal-length drive axle systems. A—In unequal-length drive axle systems, the right and left axles are different lengths. B—In equal-length drive axle systems, an intermediate shaft is added on the long side of the transaxle. Consequently, both CV axles are the same length.

undesired turning effect called **torque steer**. Torque steer is usually more noticeable on high-powered front-wheel drive vehicles, such as those equipped with turbochargers, six-cylinder engines, or eight-cylinder engines.

To overcome torque steer, some manufacturers design their drive axle systems with a separate **intermediate shaft** that is mounted between the transaxle and the CV axle on the long side of the transaxle (side farthest from its wheel assembly). The intermediate shaft allows the use of equal-length CV shafts on each side of the vehicle. This design is called an **equal-length drive axle system**, **Figure 14-3B**. When an intermediate shaft is used, it must be supported at its outer end. A bearing support bracket is generally used for this purpose. An extra CV joint or another type of flexible joint is often used to join the intermediate shaft to the transaxle differential. **Figure 14-4** shows the differences between the equal- and unequal-length drive axle systems used by one manufacturer.

Figure 14-5 shows an intermediate shaft being used on a vehicle with front-wheel drive and a longitudinal engine. This design uses a separate differential assembly that resembles the common rear-wheel drive differential. Note that the intermediate shaft used with this drive system does not have an inboard flexible joint.

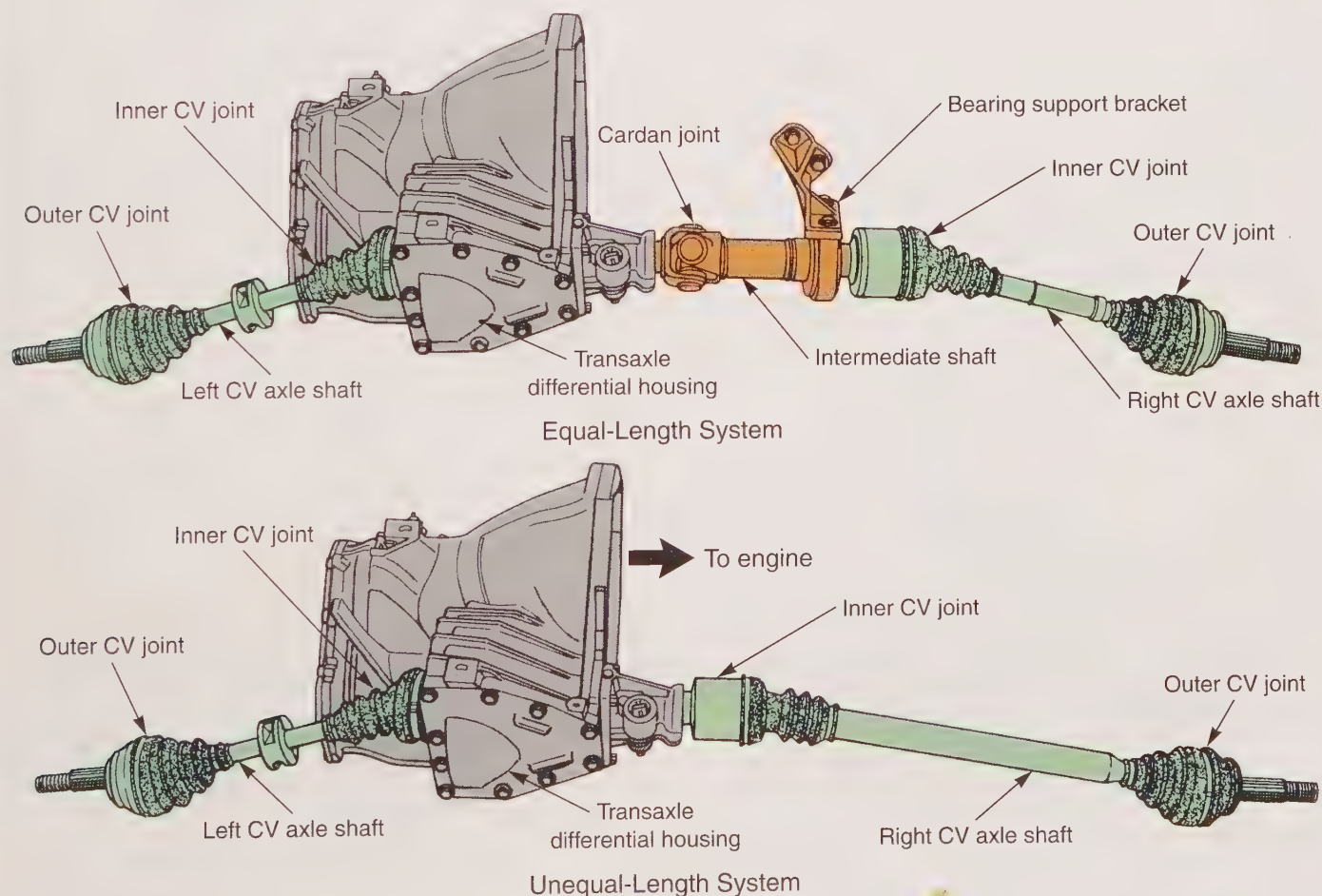


Figure 14-4. This figure shows both the equal- and the unequal-length drive axle systems used by one manufacturer. Note that the intermediate shaft requires support near its outboard end and contains a Cardan-type flexible joint on its inboard end. (Chrysler)

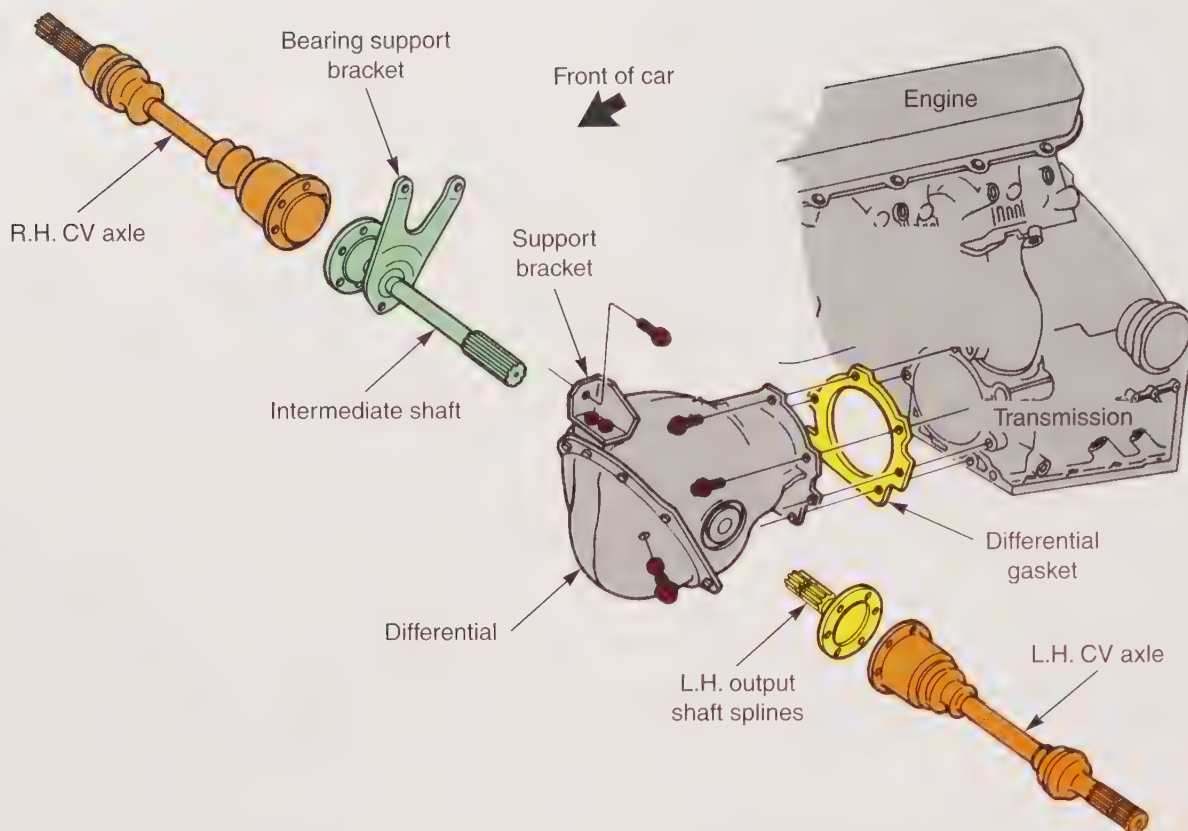


Figure 14-5. The intermediate shaft used on this front-wheel drive system has a bearing support bracket but does not use an inboard flexible joint. (General Motors)

CV Axle Power Flow

Power flow through a CV axle travels out from the side gear of the transaxle differential assembly, through the inner stub shaft and CV joint, and into the center shaft. If the assembly has an intermediate shaft, the shaft transfers power from the differential to the inner CV joint and center shaft. From the center shaft, power flows through the outer CV joint, through the outer stub shaft, and into the wheel hub.

CV Joints

On all vehicles, both the front and rear axles are designed to move in relation to the chassis. This is done so that the suspension system can absorb the bumps and jolts of uneven road surfaces. Front-wheel drive vehicles have independent suspensions, which allow each wheel to move without affecting the others.

Since the transaxle is attached to the frame or chassis of the vehicle, the drive axles must be able to flex as the drive wheels move up and down or right and left. Drive wheel movement results in an almost infinite number of possible angles through which the axles must transmit power.

As mentioned, some transaxle-equipped vehicles use one or more cross-and-roller universal joints in the drive axle system. These joints are identical to those used on the

drive shaft assembly of conventional rear-wheel drive vehicles. **Figure 14-6** shows a cross-and-roller universal joint installed at the outer end of an axle shaft. Another shaft equipped with cross-and-roller universal joints is shown in **Figure 14-7**. It resembles a small rear drive shaft assembly.

When two cross-and-roller universal joints are used on a drive axle assembly, the axle shaft usually contains internal splines to allow the shaft to change its effective length. However, some shafts do not have internal splines. Instead, a splined yoke is used at the differential. This arrangement was once common on rear-engine vehicles and was used on some older front-wheel drive systems.

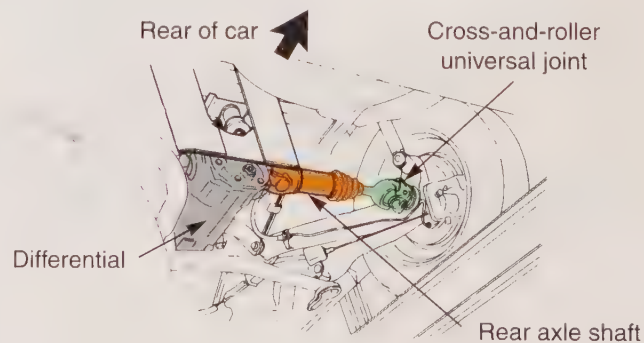


Figure 14-6. Universal joints are often used on the axle shafts of rear-wheel drive vehicles with independent suspension systems. This axle shaft uses a Cardan universal joint at the wheel.

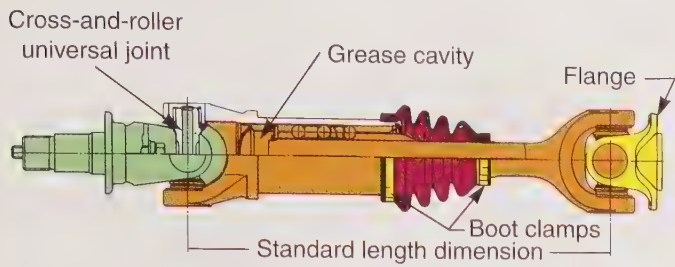


Figure 14-7. Cardan universal joints cannot compensate for changes in the effective distance between the transaxle and the wheel hubs. Therefore, an internal slip yoke is often used.

The cross-and-roller universal joint is not a constant-velocity joint. The rigid design of this joint causes the driven yoke to speed up and slow down through its rotation when the yokes are at an angle. This produces an uneven transfer of power, resulting in vibration. For more information on cross-and-roller universal joints, refer to the related discussion in Chapter 12.

The most common universal joints used in the drive axle assemblies of modern transaxle-equipped vehicles are CV joints. These joints reduce vibration, but they are more complicated than cross-and-roller U-joints. The design of a CV joint allows it to divide the drive angle equally between the shafts that are connected through the joint.

CV joints change angles using balls or spider assemblies that roll in channels. In some designs, the balls or the spider assemblies can also slide in the channels, allowing the CV joint to change its length. This compensates for changes in the effective distance between the transaxle and the wheel hub that occur when the wheels move up and down. A joint that is designed to change its length is known as a **plunging joint**. Usually, only one joint in a CV

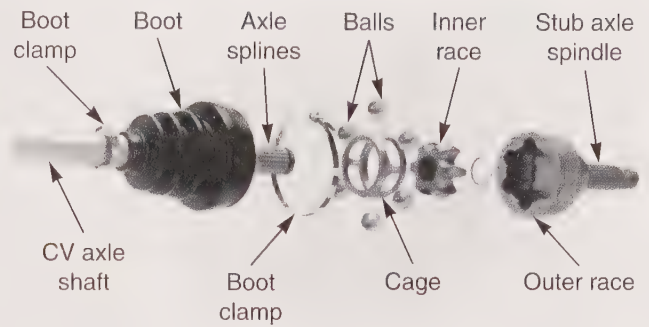


Figure 14-9. Exploded view of a ball-and-cage joint. The balls can rotate in their channels to compensate for changes in race angles. (Dana)

axle is a plunging joint. This design eliminates the need for a slip yoke.

The two major types of CV joints used in CV axles are the ball-and-cage joint and the tripod joint. **Figure 14-8** shows both types of joints installed on a single CV axle assembly. The inner joint is a tripod joint, and the outer joint is a ball-and-cage joint. When a tripod joint is used, it is almost always the inner joint and is usually a plunging joint. All CV joints are enclosed in flexible boots.

Ball-and-Cage Joints

The **ball-and-cage joint**, or Rzeppa joint, consists of a set of ball bearings, an inner race, an outer race, and a ball cage, **Figure 14-9**. The races form slotted channels that house the ball bearings. The ball cage holds the balls in place and allows them to rotate in the channels. The balls form a nonrigid connection between the races.

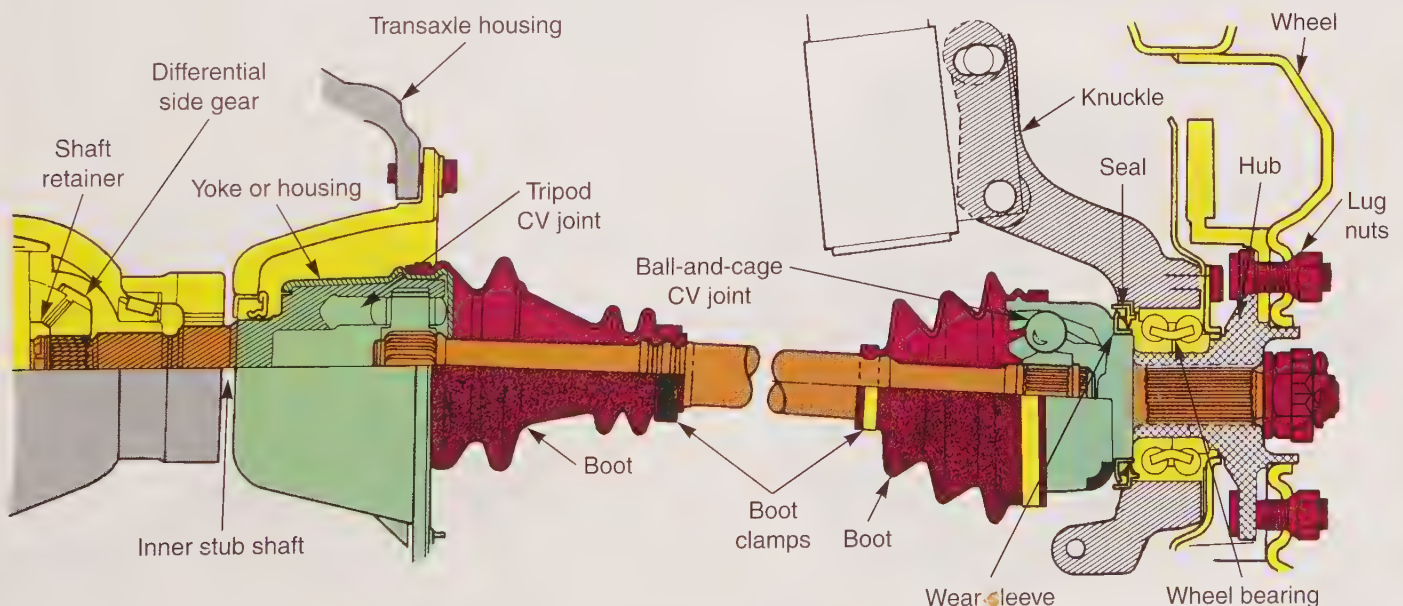


Figure 14-8. Study the two major designs of constant-velocity U-joints. When a tripod joint is used, it is usually the inboard joint. (Chrysler)

Consequently, as the drive angles change, the races can change angles without affecting each other. Power flows from the inner race, through the balls, and into the outer race. Since the balls can roll in relation to the channel in either race, they can transmit power through changing race angles without vibration.

A cutaway of a ball-and-cage joint is shown in **Figure 14-10**. The inner race of this joint is splined to the axle shaft, and the outer race is part of the stub shaft that is attached to the wheel hub. **Figure 14-11** is an exploded view of a plunging ball-and-cage joint. In this particular joint, the outer race is elongated, and the balls can move in a linear direction. With this design, the joint can compensate for changes in the effective distance between the transaxle and the wheel hub.

Tripod Joints

The **tripod joint**, or **tri-pot joint** as it is sometimes called, is used as the inboard, plunging CV joint on many CV axle assemblies. This type of joint contains a three-pointed cross, or spider, assembly, which is attached to the axle shaft through a splined connection. See **Figure 14-12**. The spider consists of three trunnions that are fitted with needle bearings and rollers. The rollers slide in channels that are cut into the outer housing of the joint assembly. Power flows into the outer housing, through the spider assembly, and into the axle shaft.

Changes in drive angle through the tripod joint are compensated for by the trunnions and rollers as they slide in the housing channels. In tripod joints, the design of the trunnions and channels allows the entire spider assembly to move back-and-forth inside the outer housing, changing the length of the joint. **Figure 14-13** is an exploded view of a typical tripod joint.

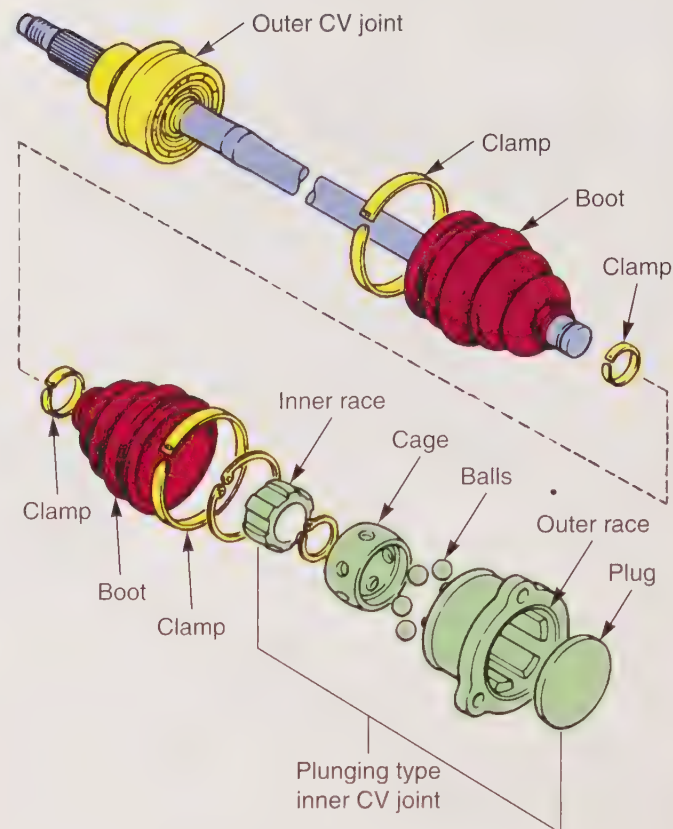


Figure 14-11. The inner CV joint shown here is a plunging ball-and-cage joint. The races in the outer housing are elongated so the balls and the cage can move back and forth. This allows for changes in axle length. (Nissan)

CV Joint Boots

As CV joints rotate, the grease that lubricates the CV joint tends to be thrown outward and away from the moving parts of the joint. Also, the placement of CV joints under the vehicle exposes them to road debris, water, and

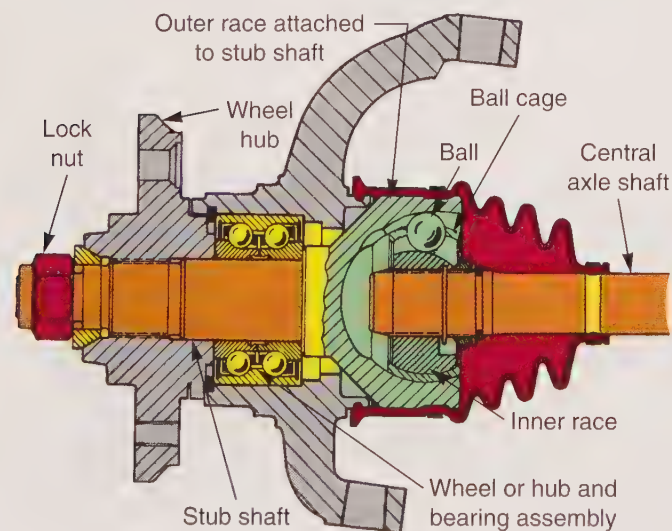


Figure 14-10. This cross section of a ball-and-cage joint shows how it is installed in relation to the steering knuckle and wheel hub. (Saab)

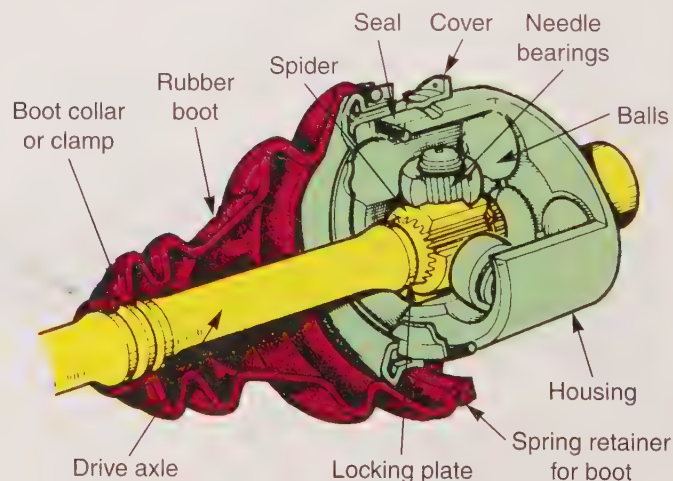


Figure 14-12. The tripod joint consists of a spider assembly and a housing with channels. The balls rotate on the spider and slide back and forth in the housing channels. (Chrysler)

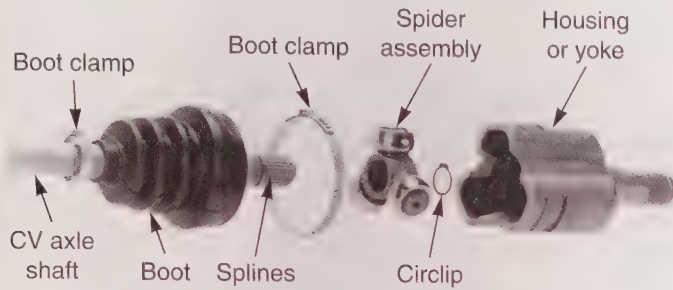


Figure 14-13. This exploded view of a tripod joint shows its major components. The spider assembly and the housing fit together to transfer power. (Dana)

other contaminants. Therefore, flexible **CV joint boots** are used to protect the joints. The boots keep the lubricant in and the contaminants out.

A typical boot installed on a CV joint is shown in **Figure 14-14**. It completely encloses the moving parts of the joint and is retained with clamps or bootstraps. The boot rotates with the axle and can flex as the drive angle changes. Boots are made of a special neoprene rubber that is not affected by the CV joint lubricant. The rubber is thick enough to resist being punctured by normal road debris. It also resists oil, water, and other contaminants.

If the boot is accidentally punctured or cut, it should be replaced. If a damaged boot is not replaced, the CV joint will be ruined by contamination and lack of lubrication. Some boots are made in two pieces and can be changed without removing the axle from the vehicle.

Figure 14-15 is a cross section of a CV joint and boot. The boot holds enough grease to maintain proper joint lubrication. Grease that is thrown from the joint strikes the inside of the boot. When the vehicle stops moving, the grease collects at the bottom of the boot. When the vehicle begins moving again, the rotating joint picks up grease from the bottom of the boot. Special pockets are sometimes molded into the boot to help distribute the grease.

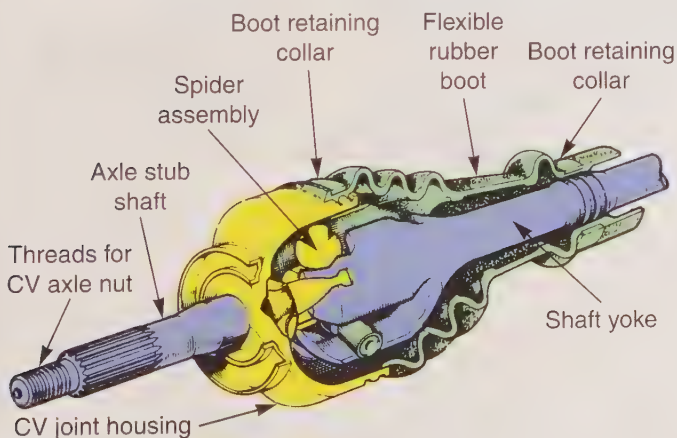


Figure 14-14. The flexible boot protects the moving parts of the CV joint and retains joint lubrication. (Chrysler)

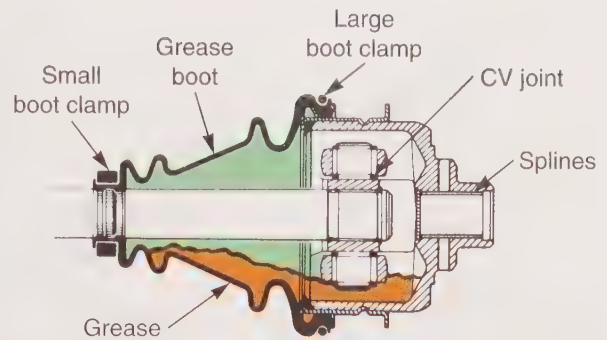


Figure 14-15. The boot should contain enough lubricant to maintain proper joint lubrication. The clamps hold the boot in place and seal the boot ends. (Chrysler)

A typical boot is illustrated in **Figure 14-16**. Notice the grease pockets, which help ensure proper lubrication. Some boots have an alignment mark to ensure proper installation on the joint and the shaft.

CV Axle Shafts

CV axle shafts are the steel shafts that work with the CV joints to transfer power between the transaxle and the wheel hubs, **Figure 14-17**. Axle shafts are made of hardened steel that is machined to fit the CV joints, the differential side gears, or the side gear flanges.

Typical CV axle shafts used on a front-wheel drive vehicle include the **central axle shaft** and the **stub shafts**. The stub shafts are connected to the center shaft through the CV joints. In many systems, one or both stub shafts are part of the outer CV joint housing.

Although a few manufacturers use tubular CV axle shafts for special applications, most CV axle shafts are solid.



Figure 14-16. A typical CV joint boot. This boot contains special pockets to hold extra grease. Proper boot size and alignment are important. (Chrysler)

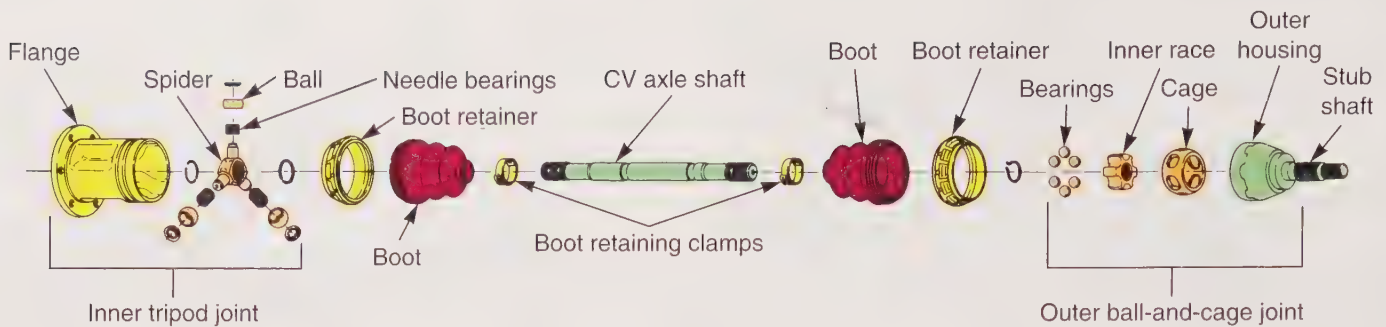


Figure 14-17. This exploded view of a CV axle assembly shows the relative positions of the axle components.

Using small-diameter, solid axles saves space in the engine compartment. Straightness and balance of front CV axle shafts are critical because of the relatively large angles these shafts must turn through. Additionally, an out-of-balance front CV axle shaft will more than likely cause a noticeable vibration that is felt in the passenger compartment.

CV axles are sometimes fastened to the transaxle with snap rings or roll pins, **Figure 14-18**. If fastened with a roll pin, the pin must be driven out before the axle can be removed from the transaxle. The snap rings used to secure some axles in the transaxle are light-tension rings. These rings can be removed by lightly prying them away from the transaxle.

Occasionally, an inner stub shaft is not used, and the inner CV joint is bolted to a flange that is part of the differential side gear assembly. Removing the flange bolts will allow the axle to be easily removed from the flange. In a few systems, the axle shafts are simply held in place by the position of the transaxle and the wheel hubs.

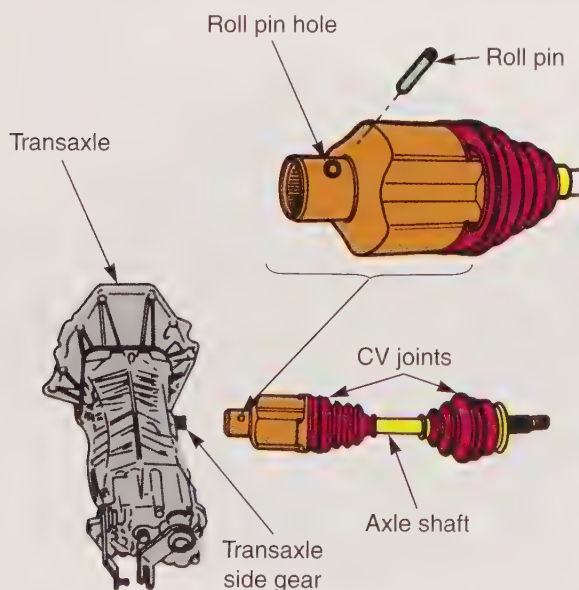


Figure 14-18. This CV axle is held to the transaxle by a roll pin. Other axles are held in place by snap rings or are bolted to a transaxle flange. (Chrysler)

CV Axle Wheel Hub and Bearing Assemblies

The CV axle stub shaft must be supported by the **wheel bearings**, which allow the shaft to transfer power through the front steering knuckle or through the rear bearing support. The steering knuckle or the bearing support acts as a housing for the bearings.

In **Figure 14-19**, the outer stub shaft, which is sometimes called the **spindle**, is supported by the **wheel hub and bearing assembly**, or the knuckle/hub assembly. The shaft passes through the knuckle and rotates on the wheel

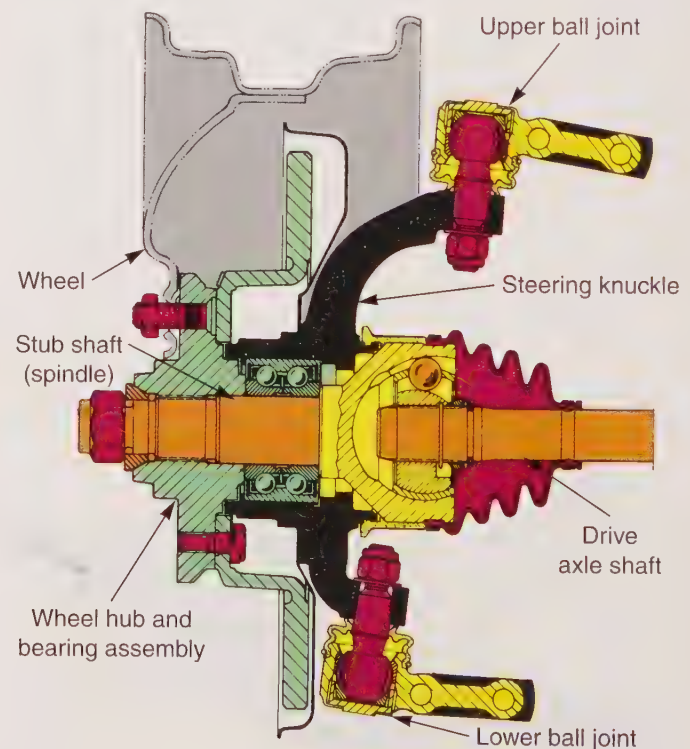


Figure 14-19. The hub and the outboard stub shaft are supported in the steering knuckle by bearings. The bearings also provide a rolling surface for the moving parts. The outboard stub shaft is often called a spindle. (Chrysler)

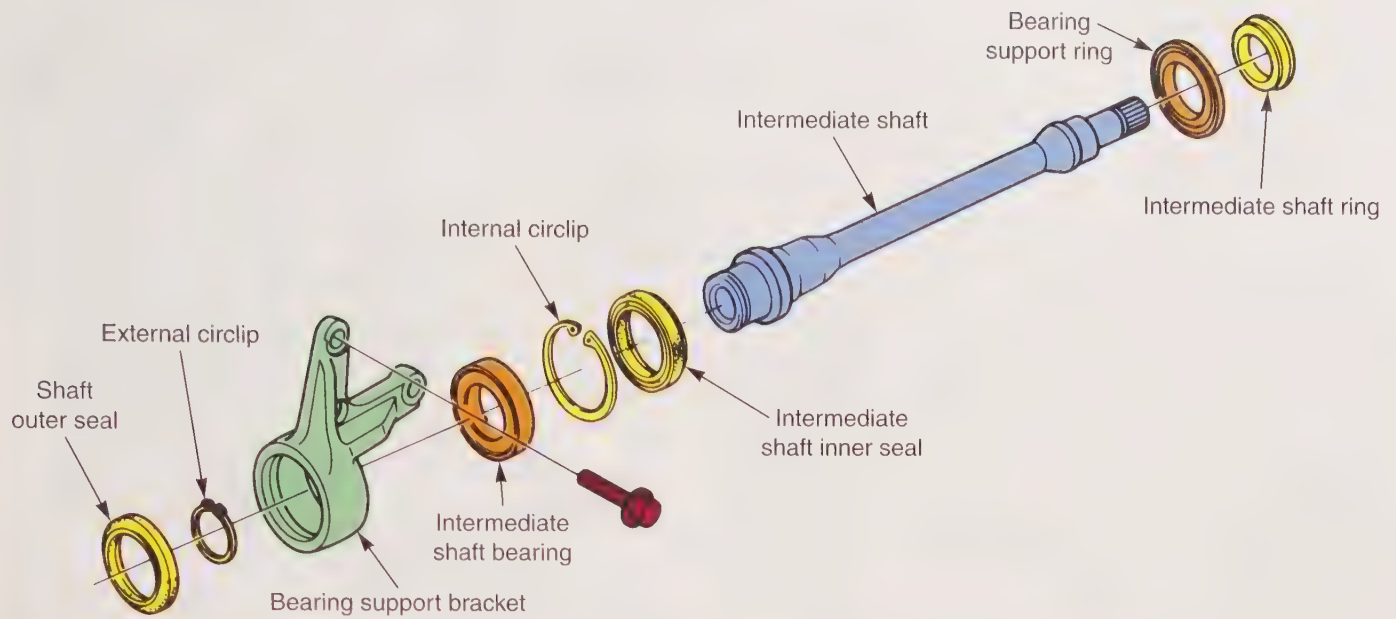


Figure 14-20. The intermediate shaft bearing is often held in a special support bracket. This bracket is attached to the transaxle or to the vehicle chassis.

bearings. The bearings support the wheel hub and maintain alignment between the hub and the knuckle.

On a vehicle equipped with an intermediate shaft, a **bearing support bracket** is installed at the outboard end of the shaft, **Figure 14-20**. The bracket houses the intermediate shaft bearing and is attached to the transaxle assembly or

to a stationary part of the vehicle chassis. The transaxle differential side gears (or flanges) support the inboard end of the intermediate shaft.

An exploded view of a typical wheel hub and bearing assembly is shown in **Figure 14-21**. The stub shaft passes through the steering knuckle to transfer power to the hub.

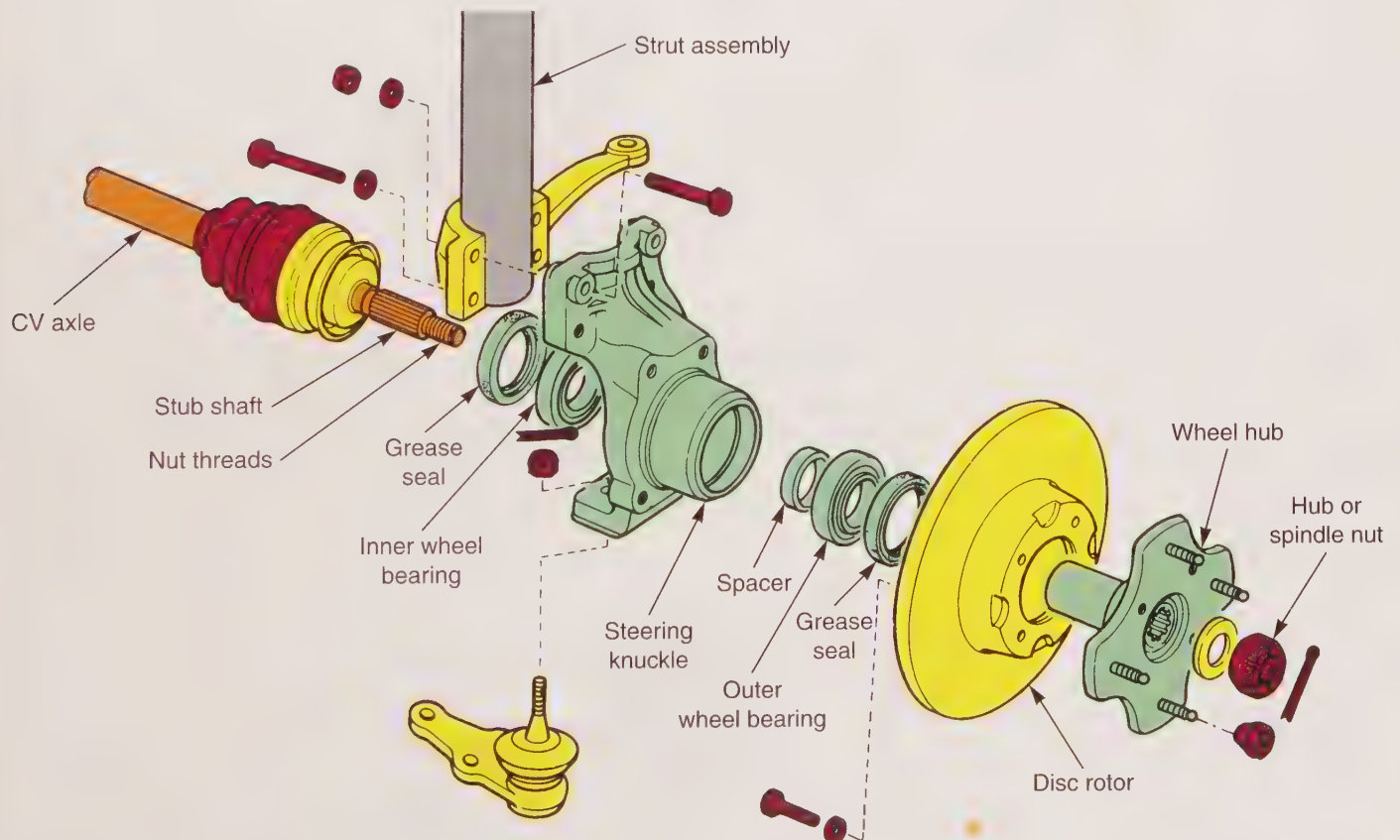


Figure 14-21. This exploded view of a spindle and a wheel hub and bearing assembly illustrates the major components on the outboard end of a CV axle. (Nissan)

The stub shaft splines fit into the internal hub splines to drive the hub. The hub and the shaft are held together with a hub nut. This particular design uses two bearings that are mounted at the front and rear of the steering knuckle.

The wheel hub and bearing assembly shown in **Figure 14-22** uses tapered roller bearings to support the axle shaft. The other parts of the assembly are similar to those shown in **Figure 14-21**. The bearing preload is adjusted by turning the hub nut.

All bearings must have an ample supply of lubricant to prevent premature wear. They must also be protected from dirt and water. Seals on the steering knuckle or the rear bearing support keep lubricant in and contaminants out. A typical lip seal is shown in **Figure 14-23**. The **wear sleeve** provides a riding surface for the sealing lip. The wear sleeve is pressed on the CV joint housing, and the seal is pressed into the steering knuckle. Many wheel hub and bearing assemblies also have a seal at the outboard end of the steering knuckle.

Figure 14-24 shows the positions of two CV axle assemblies in relation to the front suspension system, the steering system, and the front wheels. This system does not contain an intermediate shaft. For more information on bearings, see Chapter 4.

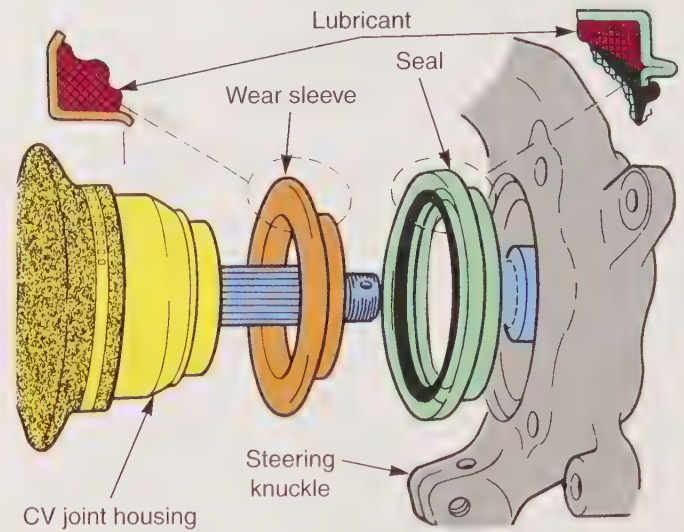


Figure 14-23. Like all moving parts, front wheel bearings require a supply of lubricant. Seals prevent the lubricant from leaking. (Chrysler)

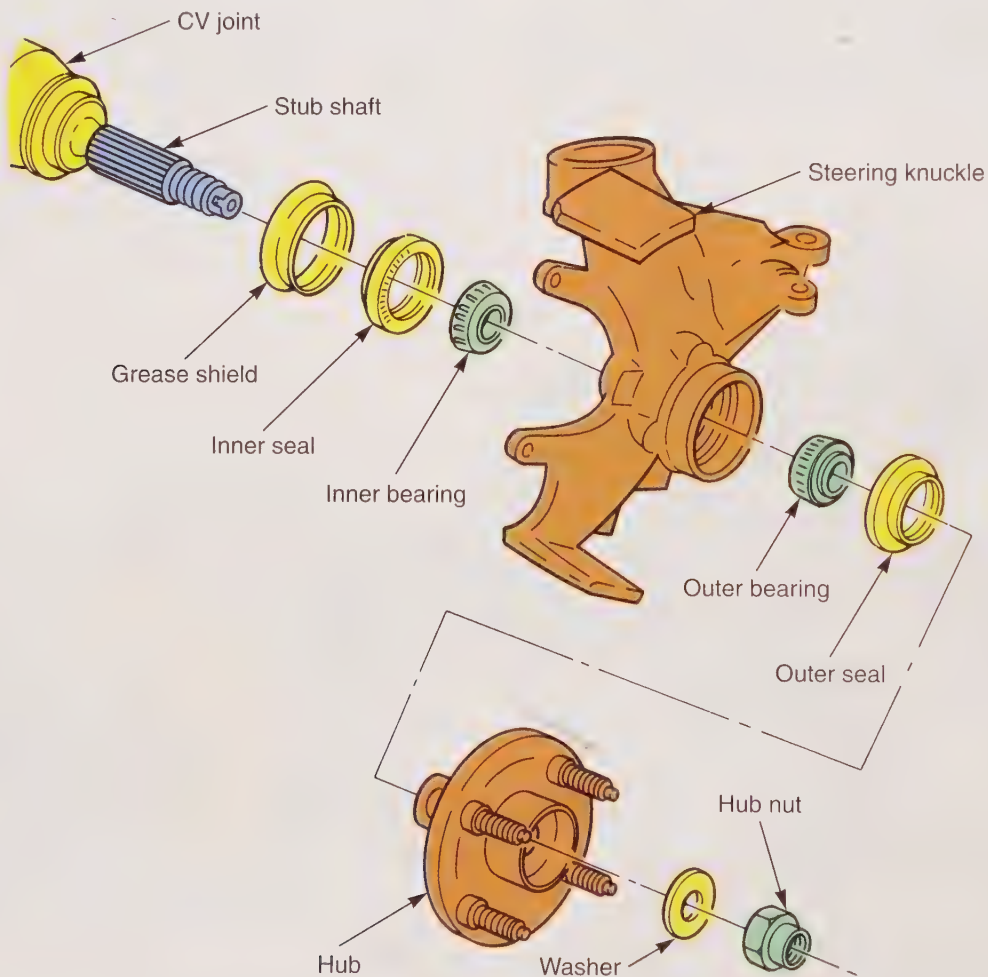


Figure 14-22. This CV axle design uses tapered roller bearings. The bearing preload is adjusted in the same manner as for front wheel bearings on a rear-wheel drive vehicle. (Ford)

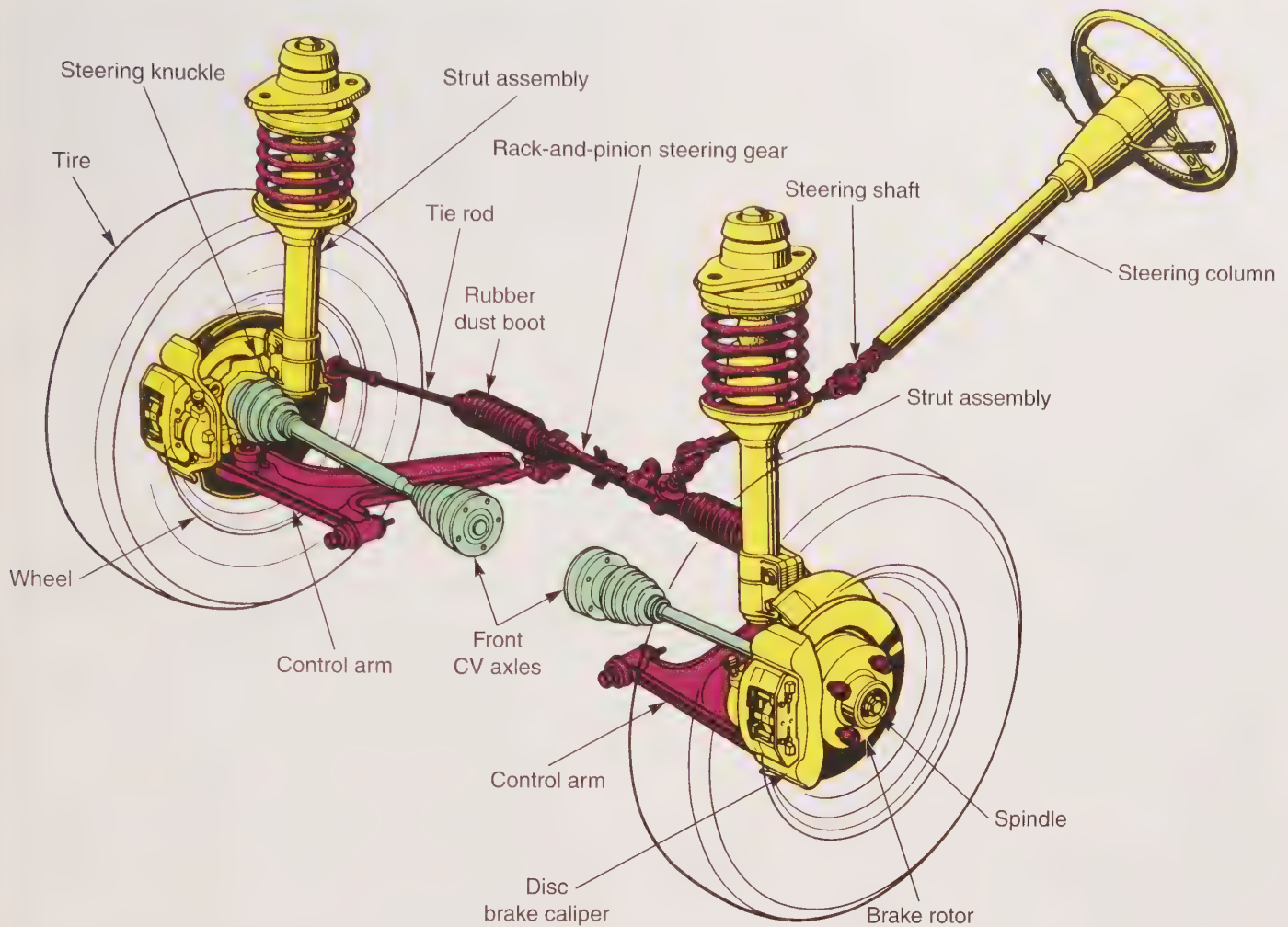


Figure 14-24. Study the position of the front CV axles in relation to the other front-end components. These axles are attached to the transaxle through bolted flanges.

Summary

Constant-velocity axles transfer power from the transaxle to the wheels. The axles are driven by the side gears of the transaxle differential. The front steering knuckles or the rear bearing supports hold the axle shafts at their outer ends.

CV axle assemblies contain CV axle shafts and CV joints. CV joints transfer power more smoothly than Cardan universal joints, which are used in rear-wheel drive shaft assemblies.

Transaxle-equipped vehicles can have equal- or unequal-length drive axle systems. The unequal-length system has two axle shafts of different lengths. This is because the design of the transaxle places its differential outputs at different distances from respective wheel hubs. The equal-length system uses an intermediate shaft on the long side of the transaxle. The intermediate shaft makes it possible to use drive axles of equal length on both sides of the transaxle. The equal-length drive axle system reduces torque steer and traction problems. It is usually found on high-powered front-wheel drive vehicles.

Cardan joints are occasionally used on some parts of the front-wheel drive CV axle, but they are not true CV joints. These joints are used on front axles only when there is relatively little change in drive angles. There are two major types of CV joints: the ball-and-cage joint and the tripod joint.

The ball-and-cage joint uses steel ball bearings that move between channels in the inner and outer races of the joint. Power flows from the inner race, through the balls, and into the outer race. Since the balls can roll in relation to the channel in either race, they can transmit power through changing race angles without vibration.

The tripod joint contains a spider assembly that consists of three trunnions. The trunnions are fitted with rollers that can turn in relation to the spider. The rollers can slide and rotate in the channels in the outer housing. Power flows from the outer housing channels, through the spider assembly, and into the axle shaft. The ability of the spider assembly to slide in the housing channels allows the joint to transmit power without vibration.

Some ball-and-cage joints and most tripod joints are designed to compensate for changes in the effective distance between the transaxle and the wheel hub. These joints have longer channels in their outer races so the balls or the spider assembly can slide as necessary. Joints with this sliding action are called plunging joints.

All CV joints must be covered by flexible boots. The boots keep lubricant in and contaminants out. CV joint boots are made of heavy neoprene rubber that resists oil, grease, and road debris. The boots are held to the CV axle shafts and the CV joint housings by clamps or straps.

The types of axle shafts found on a typical front drive vehicle include a central axle shaft and one or more stub shafts.

Bearings in the front steering knuckle or the rear bearing support secure the outboard stub shaft, or spindle, and hold the shaft and wheel hub in alignment. Some manufacturers use ball bearings, while others use adjustable tapered roller bearings.

Review Questions—Chapter 14

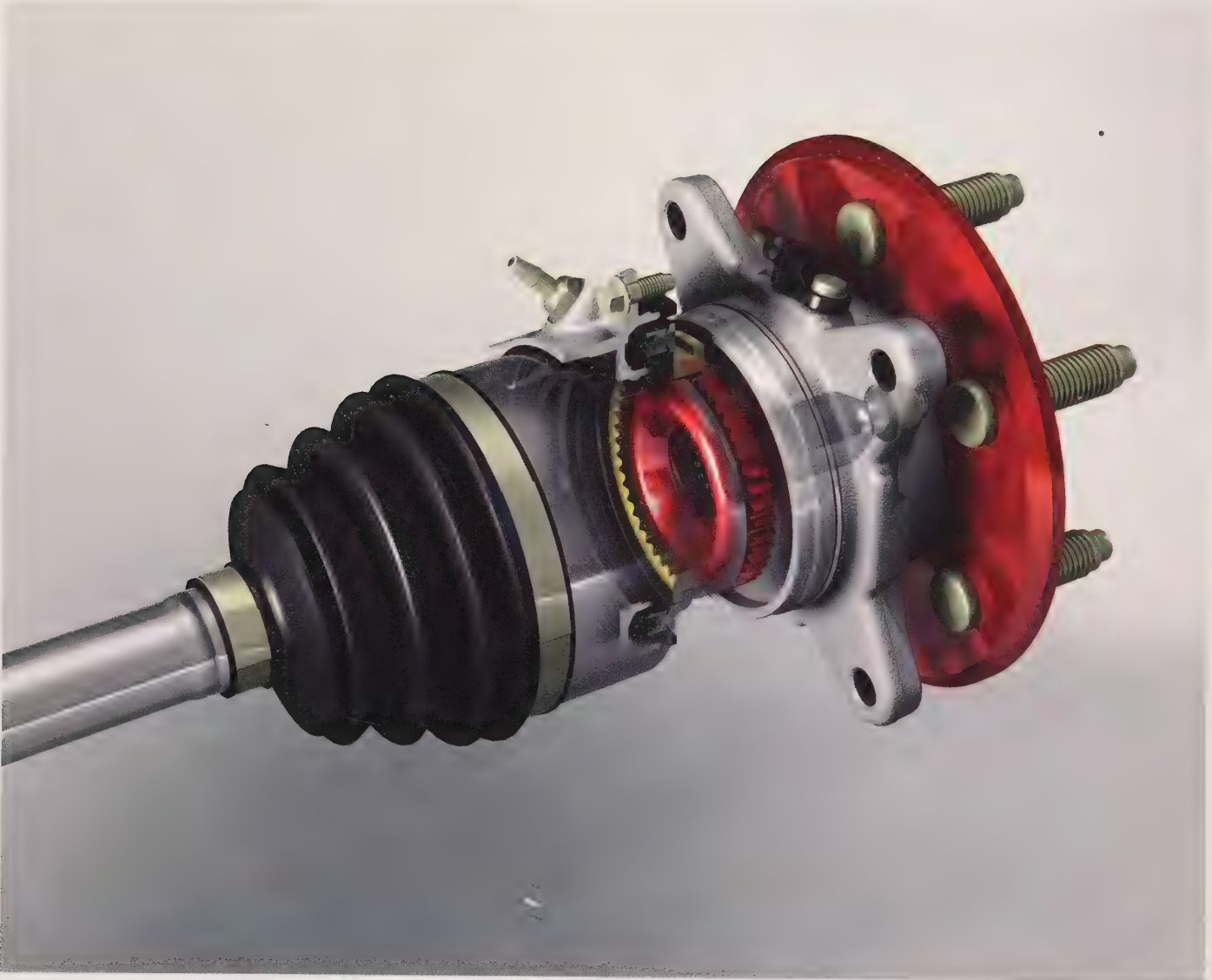
Answer the following questions using the information provided in this chapter.

1. A CV axle shaft will always have at least ____ CV joints.
2. Explain what torque steer is.
3. To prevent torque steer in unequal-length drive axle systems, a(n) ____ can be used on the long side of the transaxle.
4. How does a CV joint operate?
5. The design of a(n) ____ joint allows it to divide the drive angle equally between the shafts that are connected through the joint.
6. What is a plunging CV joint?
7. Explain the difference between a ball-and-cage joint and a tripod joint.
8. Why is a CV joint boot important?
9. The steering ____ or bearing ____ acts as a housing for the wheel bearings.
10. A wear ____ can sometimes be pressed on the CV joint housing.

ASE-Type Questions—Chapter 14

1. In transaxle-equipped vehicles, engine power is transferred from the transaxle to the drive wheels by the _____.
 - (A) CV axles
 - (B) U-joints
 - (C) intermediate shaft
 - (D) transaxle differential
2. The difference in drive angles in an unequal-length drive axle system may cause an undesired turning effect referred to as _____.
 - (A) splining
 - (B) drive slip
 - (C) torque steer
 - (D) wheel hop
3. The design of the cross-and-roller universal joint causes each of the following *except*:
 - (A) vibration.
 - (B) constant velocity.
 - (C) a slower driven yoke.
 - (D) uneven power transfer.
4. The most common universal joints used in the drive axle assemblies of modern transaxle-equipped vehicles include each of the following *except*:
 - (A) cross-and-roller U-joints.
 - (B) tripod joints.
 - (C) Rzeppa joints.
 - (D) ball-and-cage joints.
5. CV joint boots are used to do each of the following *except*:
 - (A) keep lubricant in.
 - (B) protect CV joints.
 - (C) prevent vibration.
 - (D) keep contaminants out.
6. CV axle shafts work with CV joints to transfer power between the transaxle and the _____.
 - (A) engine
 - (B) wheel hubs
 - (C) wheel bearings
 - (D) rear axle assembly

7. Technician A says that straightness and balance are critical on front CV axle shafts because of the relatively large angles they must turn through. Technician B says that an out-of-balance front CV axle shaft will more than likely cause a vibration that is felt in the passenger compartment. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
8. For it to transfer power, the CV axle stub shaft must be supported by the _____.
 - (A) spindle
 - (B) central shaft
 - (C) CV axle shaft
 - (D) wheel bearings
9. Each of the following is considered a true CV joint *except*:
 - (A) tripod joints.
 - (B) Cardan joints.
 - (C) Rzeppa joints.
 - (D) plunging joints.
10. The inboard end of a CV axle is connected to _____.
 - (A) a wheel hub
 - (B) the rear bearing support
 - (C) the transaxle differential
 - (D) a stub axle
11. Each of the following statements about steering knuckles is true *except*:
 - (A) they keep grease circulating.
 - (B) they pivot to turn front wheels.
 - (C) they connect to front suspension parts.
 - (D) they are mounting attachments for wheel hubs.
12. CV axle shafts include each of the following *except*:
 - (A) stub shafts.
 - (B) spindles.
 - (C) center shafts.
 - (D) transfer shafts.



Front wheel hub assembly. (Ford)



Chapter 15

Constant-Velocity Axle Problems, Troubleshooting, and Service

After studying this chapter, you will be able to:

- ☐ Troubleshoot axle problems.
- ☐ Remove and replace a CV axle.
- ☐ Disassemble and reassemble a CV joint.
- ☐ Install a new CV joint.
- ☐ Install a new CV joint boot.
- ☐ Replace front-drive axle wheel bearings.

Technical Terms

Abnormal noises

CV axle vibration

Lubricant leakage

Boot protector

Metal ladder clamps

Rubber rings

Metal spring clamps

Strap-and-buckle clamp

Introduction

The importance of CV axle diagnosis and repair has grown as the number of front-wheel drive vehicles on the road has increased. This chapter explains the proper ways to diagnose and service CV axle assemblies.

Chapter 14 contained information on the construction and operation of CV axles. If you encounter a term or concept in this chapter that you do not understand, review the material in Chapter 14.

CV Axle Problems and Troubleshooting

Although the CV axle is a relatively simple device, it is subject to several problems. See **Figure 15-1**. CV axle problems can be grouped into three general categories: noises, vibrations, and lubricant leaks. Before deciding a CV axle is defective, make sure the problem is not caused by a defect in the engine, transaxle, brakes, steering and suspension components, wheels, or tires. Since these components are generally located in the front of the vehicle, it is easy to mistake sounds from these components for CV axle noises.

Abnormal Noise

Abnormal noises in the CV axles are unusual sounds, such as clunking, popping, or clicking noises that are caused by defective CV axle components. Most CV axle noises occur when the wheels are turned or the brakes are applied. Dry or worn front wheel bearings, on the other hand, generally produce rumbling or roaring noises that vary with vehicle speed.

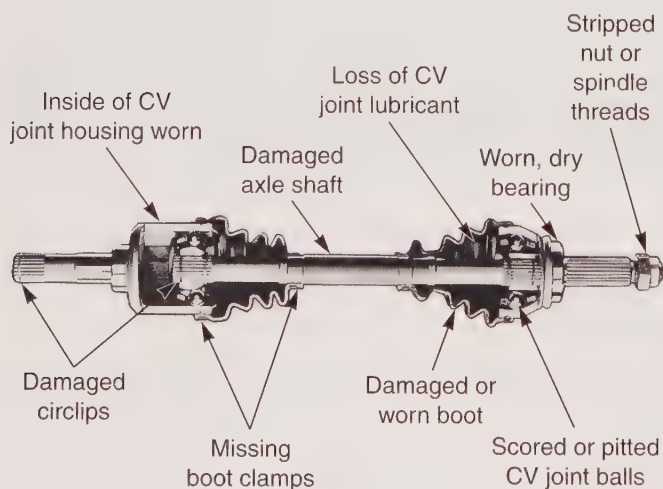


Figure 15-1. Study the common CV axle problems.
(Champion Parts)

One of the most common causes of CV axle noise is a lack of lubricant in a CV joint. Lubricant may dry out after extensive use, or it may leak out through a damaged boot. A dry CV joint usually makes a popping, clicking, or snapping sound. Sometimes, regreasing the joint will solve the problem. Often, however, the joint will be worn or rusted and must be replaced or rebuilt.

Another cause of CV axle noise is a worn CV joint. Wear can occur at any point where the CV joint components move in relation to each other. Worn parts generally cause the joint to clunk or knock when the vehicle is turned or the brakes are applied. In some cases, the suspension attaching bolts or the axle bolts become loose, allowing movement between parts.

It is sometimes difficult to determine which joint in a CV axle assembly is defective. It may be possible to see excess movement between parts on either side of a defective CV joint. To check for movement, raise the vehicle. If the vehicle has an automatic transaxle, put it in park. If the vehicle has a manual transaxle, it can be placed in any gear. Try to turn the wheel on the problem axle with your hand and observe the axle shafts on both sides of the suspected CV joint. Excess movement indicates a worn or damaged joint. It may help to compare movement around the joints on both sides of the vehicle. If one joint is looser than the others, it is probably defective.

Repairing a noisy CV axle can be as simple as tightening loose bolts. At the other extreme, a noisy CV axle could mean that a complete rebuild of the CV joints is necessary.

CV Axle Vibration

CV axle vibrations are pulsations or other cyclical shocks caused by worn or damaged CV axle parts. Vibrations may be caused by a bent or twisted axle shaft, worn CV joints or wheel bearings, or loose attaching bolts. Always check for worn or loose parts when vibrations are evident. If a bent CV axle shaft is suspected, it may be necessary to check the runout of the shaft.

Most vibrations will be felt through the steering wheel and, in some cases, the vehicle body. The frequency of CV axle vibrations will increase as vehicle speed increases. Since the CV axles are commonly used at the front of a vehicle, even slight vibrations will be noticeable. The usual cure for CV axle vibrations is the replacement of defective components.

Lubricant Leakage

CV axle **lubricant leakage** generally originates from the CV joints or the wheel bearings. Most CV joint leaks are caused by torn boots or loose boot clamps. Wheel bearing lubricant will leak from a defective bearing seal. In some cases, transaxle fluid will leak from a defective seal between the transaxle housing and the CV axle shaft.

Most leaks from the CV axle system show up as grease or oil splattered on the underside of the vehicle near the leaking boot or seal. Grease may also be found on the boot or seal itself. Leaking seals may leave a trail of grease or oil that originates under the seal. If you squeeze a CV joint boot and hear air escaping, there is a hole in the boot or a loose clamp. Leaking boots and seals should be replaced promptly.

CV Axle Safety Precautions

CV axles rotate at high speeds and can cause severe damage. When checking for CV axle problems, always keep the following safety precautions in mind:

- ❑ If you are running the vehicle on a lift, always stay away from the spinning axles.
- ❑ When spinning the axle shafts with the vehicle on a lift, *always* support the lower control arms so the front wheels are at or near their normal position in relation to the vehicle body. Allowing the wheels to hang while being driven will cause the CV joints to drive through excessive angles and could cause a joint to bind, break, or fly apart violently.
- ❑ When testing a front-wheel drive vehicle on a lift, *never* exceed a speedometer reading of 30 mph (48 km/h).
- ❑ If you road test the vehicle to check CV axle operation, *always* choose uncongested areas and obey all traffic regulations. This will help prevent accidents.

Road Testing

It is often necessary to road test a vehicle to determine the exact source of a problem. Often, a problem cannot be duplicated in the shop, and a road test must be conducted.

When performing a road test, try to isolate CV axle problems from engine, transaxle, tire, and other vehicle problems. Rumbling or roaring noises that increase and decrease only slightly with vehicle speed are usually caused by bad bearings. Vibrations that cycle according to vehicle speed generally indicate CV axle problems, not engine or transmission trouble.

Many clunking or popping noises in the CV axle can be diagnosed by driving the vehicle in a quiet parking lot. As the vehicle moves slowly forward, turn the wheels sharply from side to side, **Figure 15-2**. This will help isolate many noises. Applying the brakes with varying force may also help you to isolate noises. Remember to check carefully to eliminate the steering or suspension system as the source of the noises.

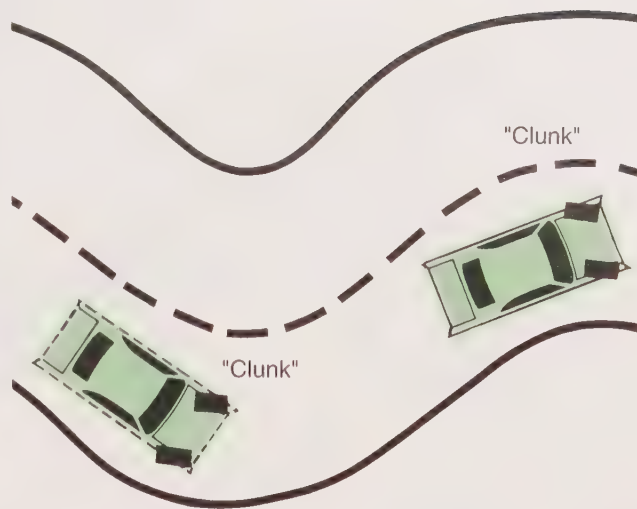


Figure 15-2. Turning the wheels from side to side will change the loads on the CV axles, isolating noises from loose or worn parts. Braking and accelerating may also help isolate the noise. (Chrysler)

from a vehicle when the CV joint, axle shaft, boot, or wheel bearing requires service. Almost all CV axle and wheel bearing repairs require that the axle be removed from the vehicle.

The CV axles must be removed from the transaxle before removing the transaxle from a vehicle. On many front-wheel drive vehicles, the engine and transaxle must be removed as a unit. Therefore, the CV axles must often be removed before the engine can be removed. In many cases, the CV axles can be pulled from the transaxle without removing them from the wheel hub and bearing assemblies.

There are many variations to the basic CV axle design. The following procedure provides a general guide for removing most common CV axles. Always consult the manufacturer's service manual for the exact removal procedures.

1. Disconnect the vehicle's battery negative cable.
2. Place the vehicle transaxle in Neutral.
3. Raise the vehicle and support it on approved jack stands. With some designs, you may want to loosen the stub shaft nut before raising the wheels off the floor. Remove the wheel from the wheel hub on the side to be serviced.
4. Cover the outer CV joint boot with a shop cloth, tape, or a **boot protector**. See **Figure 15-4**. This will help prevent damage to the boot. If needed, remove the tie rod end nut and use a ball joint separator to free the tie rod end from the steering knuckle, **Figure 15-5**.
5. Remove the stub shaft nut cotter pin, and then remove the stub shaft nut, **Figure 15-6**. A few vehicles have left-hand threads on the right stub shaft. To remove the nut, it must be turned in a clockwise direction. Always check the service information before trying to remove the stub shaft nut.

CV Axle Removal

Figure 15-3 shows the parts of a typical CV axle assembly. These components must generally be removed

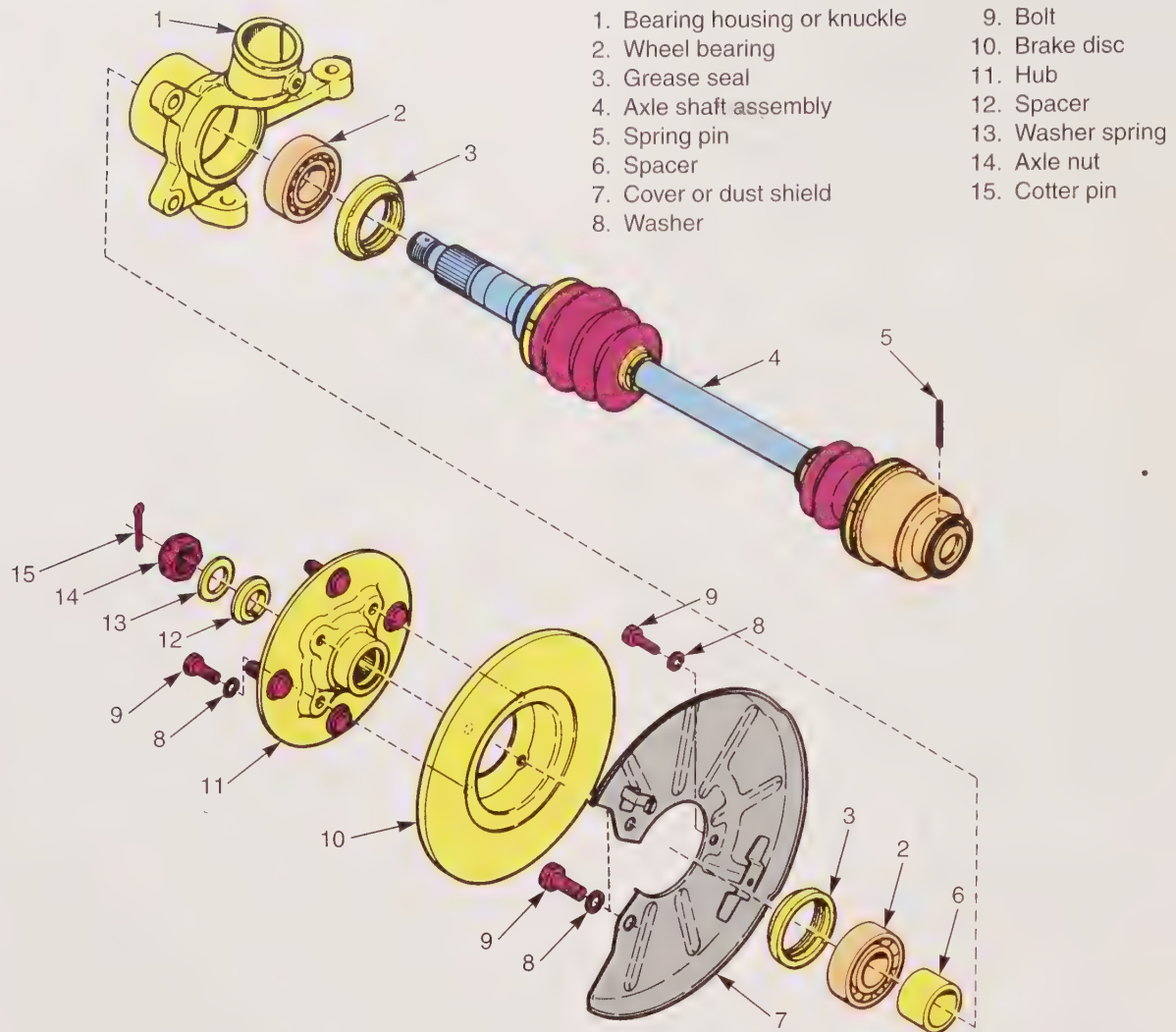


Figure 15-3. Exploded view of a typical CV axle and related components. Most transaxle-equipped vehicles have similar components. (Subaru)

6. If tapered roller bearings are used for wheel bearings, remove the washer and the outer wheel bearing. Some bearing assemblies are equipped with a tensioning spring, which should also be removed at this time. Some vehicles use ball bearings, which must be pressed from the steering knuckle. The procedure for removing these bearings will be covered later in this chapter. Store all parts so they will not get damaged or dirty.



Note: The steering knuckle may not have to be removed when removing the CV axle. In some cases, however, the steering knuckle must be removed with the axle and the rest of the wheel hub and bearing assembly. These components can then be disassembled on a workbench. Always consult the manufacturer's service information for exact procedures.

7. Before removing the wheel hub and bearing assembly, remove the brake caliper, **Figure 15-7**. Most calipers

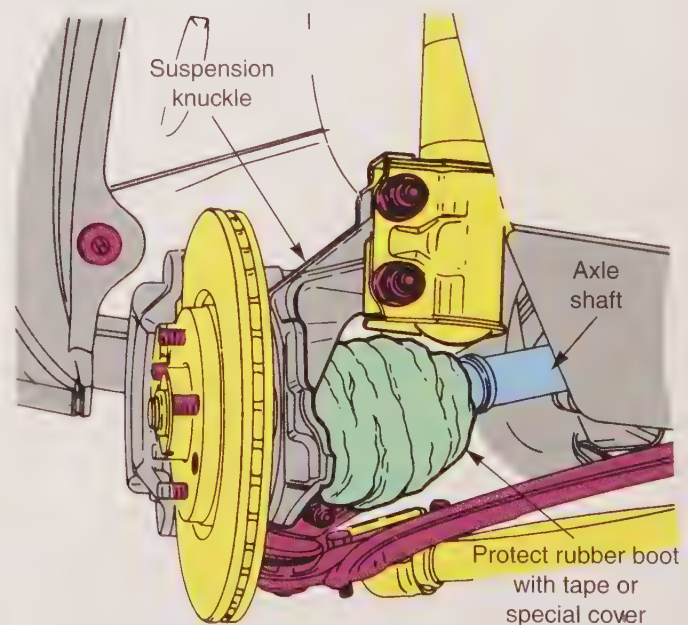


Figure 15-4. After removing the wheel and tire, cover the CV axle boot with a cloth or protector to prevent damage during axle removal. (General Motors)

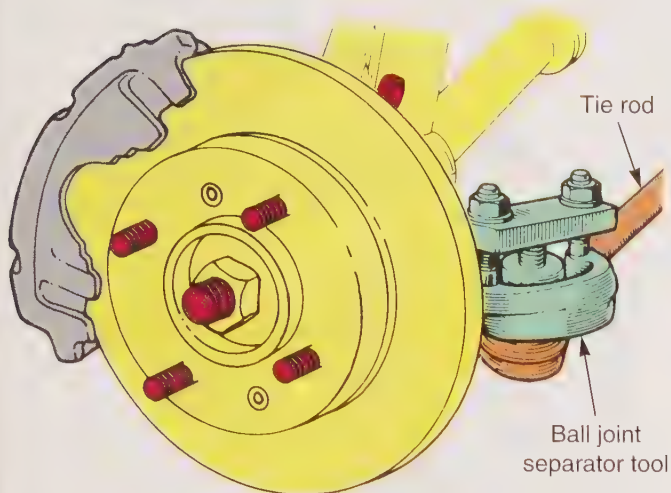


Figure 15-5. The tie rod end should be removed from the steering knuckle with a special tool. Never pound on the tie rod shaft. Pounding may damage the threads. (Chrysler)

can be removed without opening the hydraulic system. Pry the pads away from the rotor and remove the caliper attaching bolts. Position the caliper so that the brake hose is not strained. In many cases, the caliper can be wired to the vehicle chassis.

8. After removing the caliper, pull the wheel hub and bearing assembly from the axle stub shaft. In some cases, the bearings are pressed in the assembly, and the assembly must be removed with a puller. See **Figure 15-8**.
9. If necessary, remove the nut or the clamp bolt holding the ball joint stud to the steering knuckle, and separate the ball joint stud from the knuckle. See **Figure 15-9**.

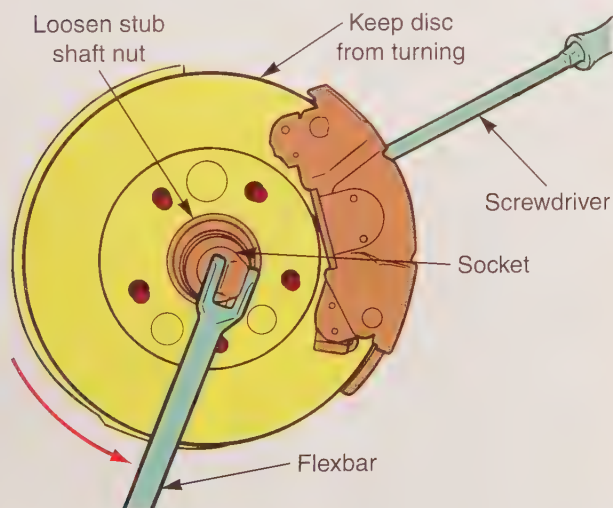


Figure 15-6. The spindle nut, or hub nut, can be removed with a large breaker bar and a socket. Leave the tire on the floor or have an assistant step on the brake to prevent the rotor from turning. If necessary, a screwdriver can be used to hold the rotor in place. (General Motors)

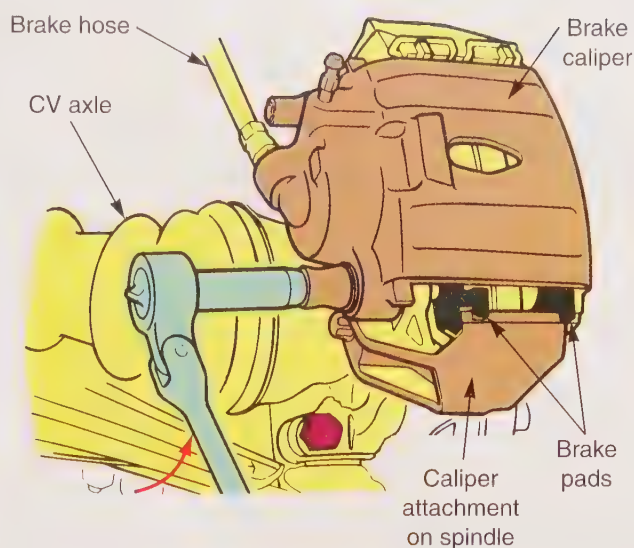


Figure 15-7. Remove the brake caliper before removing the rotor and wheel hub and bearing assembly. The caliper can be removed by prying the pads away from the rotor and removing the attaching bolts. The hydraulic system does not have to be opened when removing the caliper. (Chrysler)

10. Free the steering knuckle by removing the bolts holding it to the lower portion of the MacPherson strut assembly, **Figure 15-10**.



Warning: If the front spring is located between the lower control arm and the frame, the control arm must be supported before removing the ball joint or strut bolts. Spring tension can cause serious injury if the control arm is not supported!

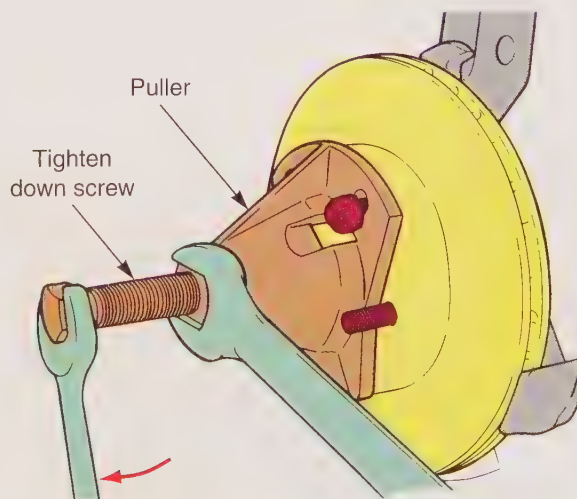


Figure 15-8. Some front-wheel drive systems use a pressed-on wheel hub and bearing assembly. A puller, such as the one shown here, can be used to remove the spindle from the hub. (General Motors)

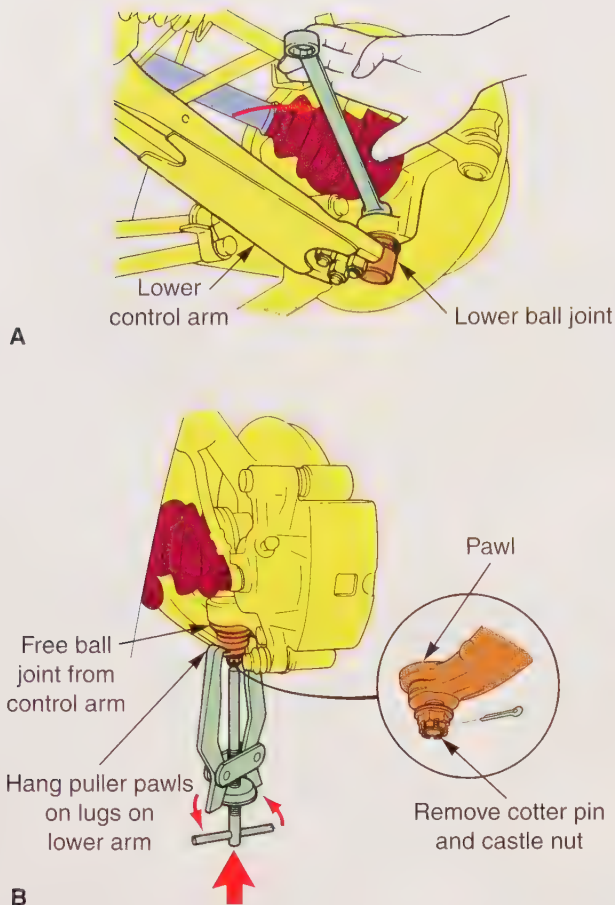


Figure 15-9. This illustration shows the removal process for a lower ball joint. Always support the lower control arm before removing the attaching nut. **A**—Removing the ball joint attaching nut with a hand wrench. **B**—Using a puller to remove the ball joint from the steering knuckle. (Subaru, Honda)

11. Pull the steering knuckle assembly away from the vehicle until it clears the CV axle shaft, **Figure 15-11**. Then, remove the knuckle. If the steering knuckle must remain attached to other suspension parts, position it out of the way. Tie the steering knuckle to the chassis with wire if necessary.

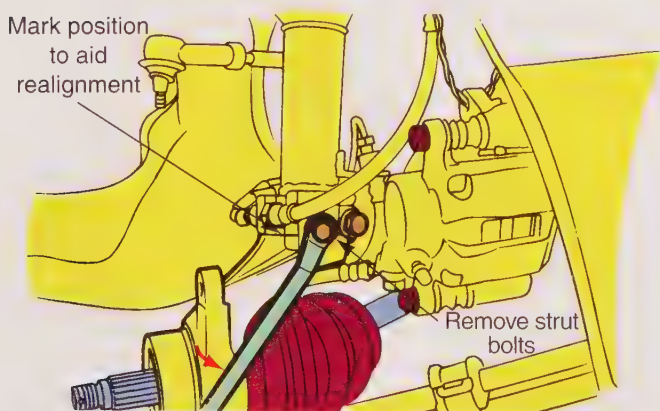


Figure 15-10. Removal of the lower bolts on a MacPherson strut suspension. Always mark the relative position of the parts to aid in front end realignment. (Chrysler)

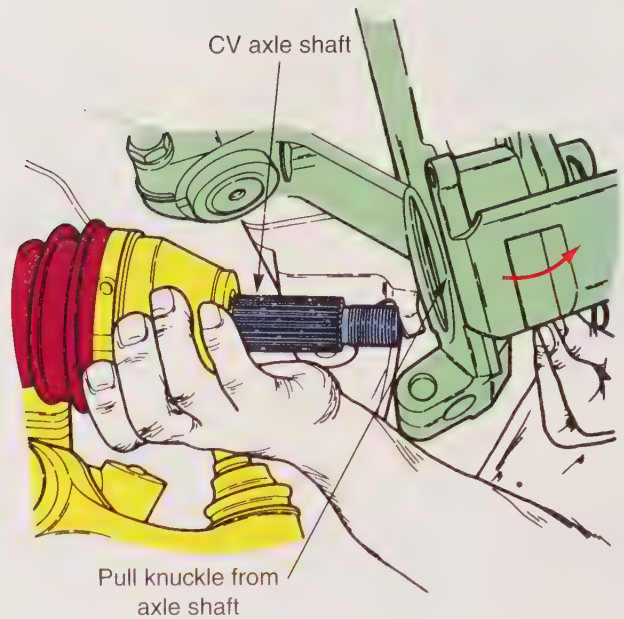


Figure 15-11. Once the other attachments are removed from the steering knuckle, it can be pulled from the CV axle shaft. (Ford)

12. If you are removing the axle that drives the speedometer drive gear, remove the gear from the transaxle.
13. You are now ready to remove the CV axle from the transaxle. The CV axles may be secured in the transaxle in one of many ways. Therefore, it is important that you consult the proper service information for the exact removal procedure. Some CV axles are splined to the differential side gears or to the intermediate shaft on the long side of equal-length drive shaft systems. Some CV axles are held in place by a clip at the transaxle. Other axles are bolted to a flange that is attached to the transaxle. During disassembly, mark all parts so they can be reassembled in the proper order.

Some CV axles must be removed with an adapter that is attached to a slide hammer. See **Figure 15-12**. The adapter jaws are placed around the inner side of the CV joint housing. The slide hammer is then used to pull the axle from the transaxle output shaft.

Some axles are attached with a retaining pin, which must be removed with a hammer and a punch, **Figure 15-13**. Once the pin is removed, the axle will slide from the transaxle output shaft. It may be necessary to pry the axle shaft loose with a pry bar placed between the inner CV joint and transaxle.

If the axle shaft is bolted to the transaxle output stub shaft, remove the bolts, **Figure 15-14**. After the bolts have been removed, pull the axle shaft from the stub shaft.

A few CV axles are held to the transaxle by an internal circlip, or snap ring, that can only be accessed by removing the differential cover, **Figure 15-15**. When

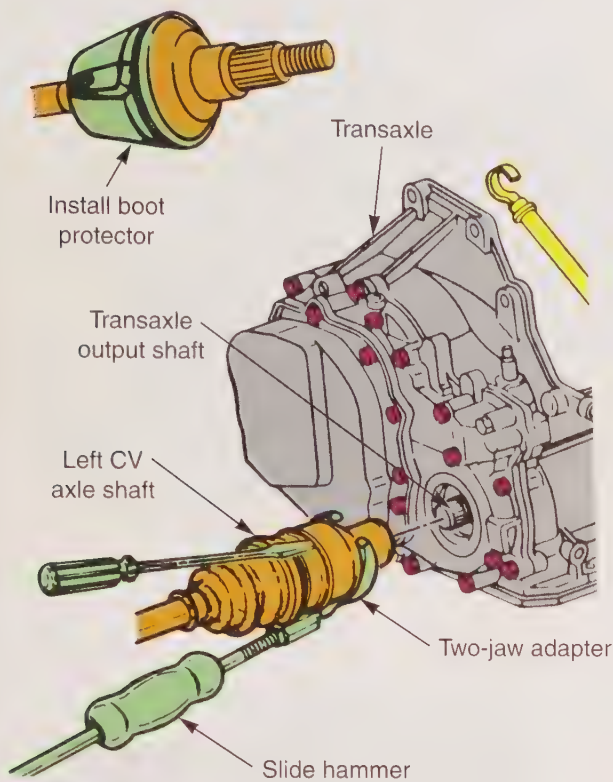


Figure 15-12. This CV axle is being removed from the transaxle with a two-jaw adapter that is attached to a slide hammer. (General Motors)

removing the cover, place a drip pan under the cover to catch spilled oil. After prying the clip from the axle, the shaft will slide out of the transaxle.

14. After the CV axle has been removed from the vehicle, place it on a clean workbench for disassembly. The bench should be equipped with a vise that is fitted with soft jaws to prevent damage to axle parts. If you suspect the axle shaft is bent, check it visually first. If no damage is visible, the shaft should be mounted on V-blocks and checked with a dial indicator.

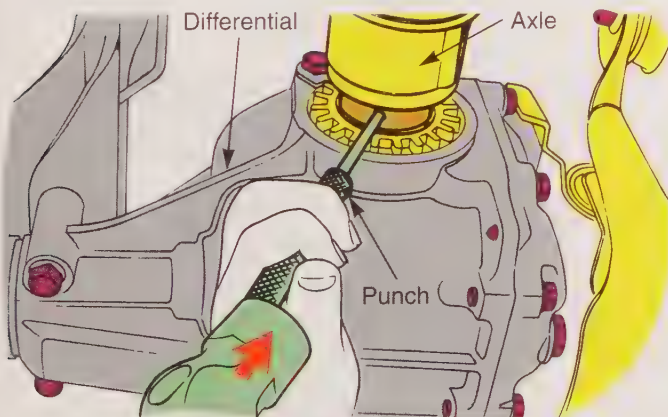


Figure 15-13. Some CV axles are held in place by a pin that is pressed through the transaxle output shaft and the CV axle shaft. After the pin is driven out, the shaft can be pried out of the transaxle.

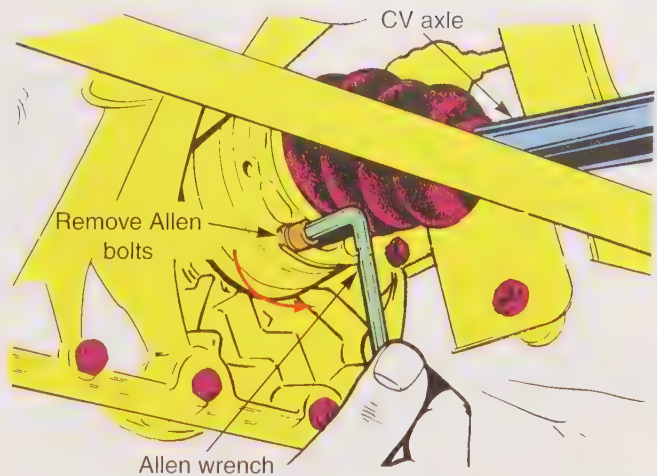


Figure 15-14. CV axles that are bolted to stub shafts at the transaxle can be unbolted and removed. Always mark the stub shafts and axle shafts before removal to ensure that they are reinstalled in their original position. (Ford)

CV Axle Parts Inspection and Repair

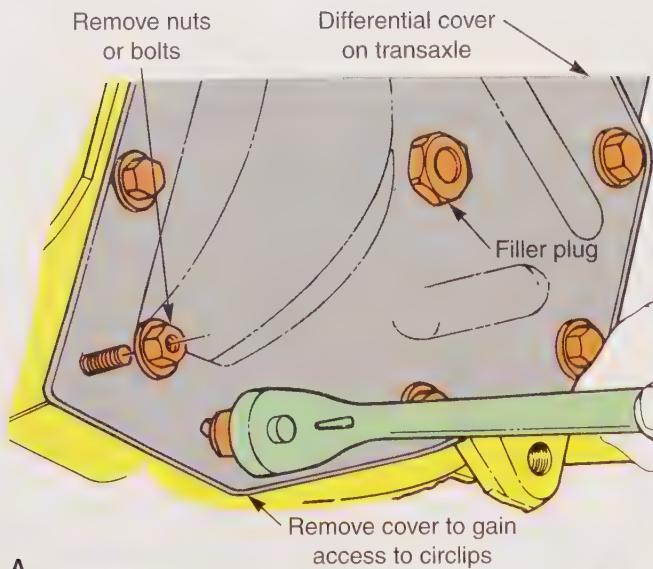
With the CV axles removed, each component must be carefully inspected for wear and damage. Be sure all parts are clean before inspection. Look for *any* signs of damage or wear, no matter how slight. After the defect is identified, the concerned part or parts may be repaired or replaced. Service procedures for the various CV axles and related parts are the focus of this section.

CV Axle Seal Service

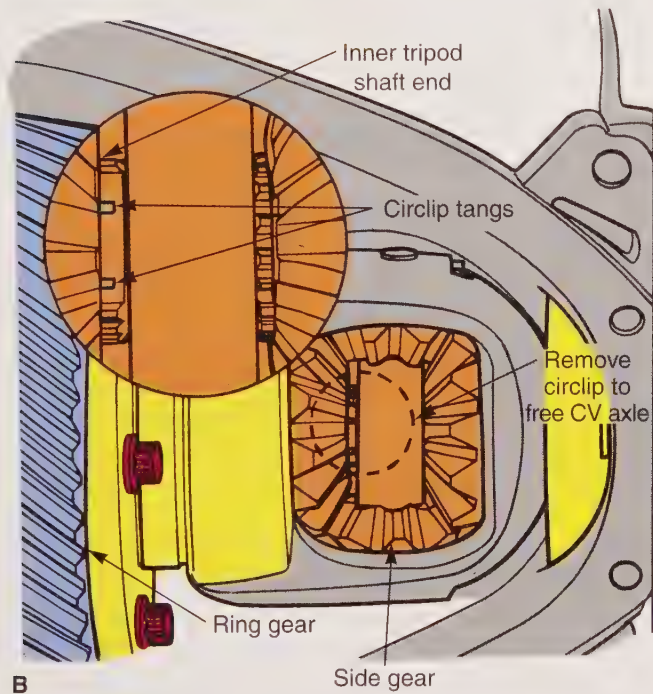
After the CV axle shaft has been removed, the axle seals can be replaced, as illustrated in **Figure 15-16**. To remove the seal, first, pry out the transaxle stub shaft, **Figure 15-16A**. (This step is skipped if there is no stub shaft at the transaxle.) Then, pry out the old seal with a large screwdriver or a seal removal tool, **Figure 15-16B**. Once the old seal is removed, install the new seal with a special installation tool, **Figure 15-16C**. Fluid may drip from the transaxle housing after the axle shaft is removed. Have a pan ready to catch the dripping fluid.

CV Axle Wheel Bearing Service

The wheel bearings used with CV axles are a common source of problems. Some manufacturers use ball bearings in the front wheel hub and bearing assemblies, while others use tapered roller bearings. The tapered roller bearings are similar in appearance to those used on the front wheels of rear-wheel drive vehicles. The wheel bearings should be carefully inspected. Bearings should be replaced if they show signs of wear, corrosion, or damage.



A

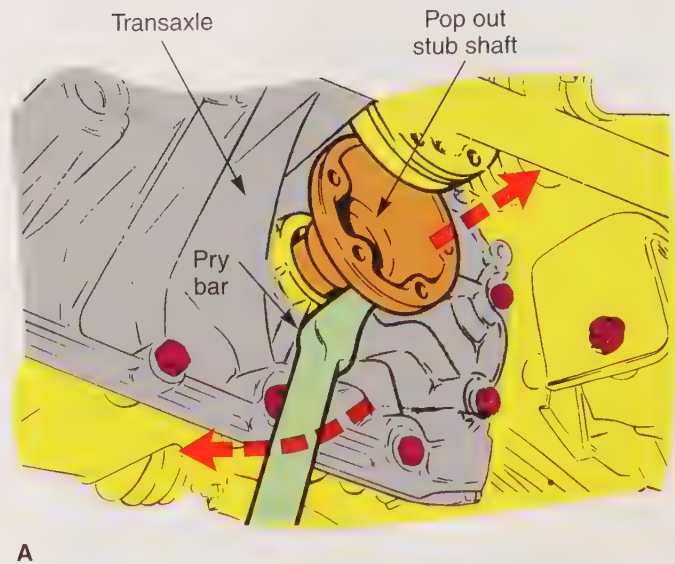


B

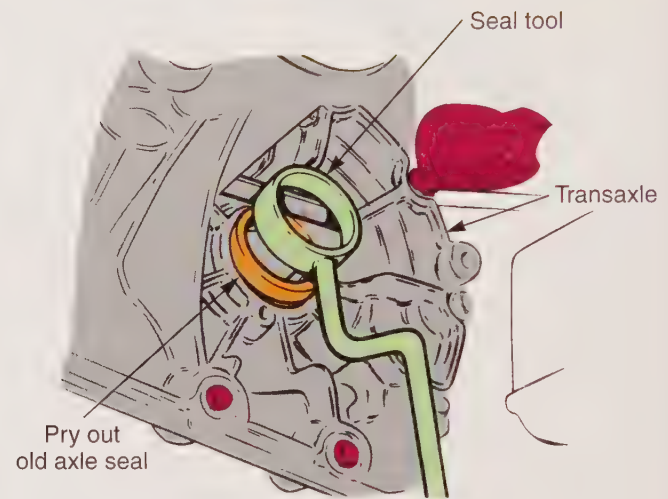
Figure 15-15. Some CV axles are held in place by a snap ring that is located inside the transaxle differential assembly. A—Removing the differential cover. B—Removing the circlip. (Chrysler)

Some wheel bearings are held in place with a snap ring and can be slid from the knuckle once the snap ring is removed. Many wheel bearings are pressed into the bearing carrier or the steering knuckle, and the wheel hub is pressed into the bearing. The first step in servicing this type of assembly is to press the hub from the bearing with a hydraulic press and a proper adapter plate, **Figure 15-17**. The bearing can then be removed from the carrier or knuckle with a puller.

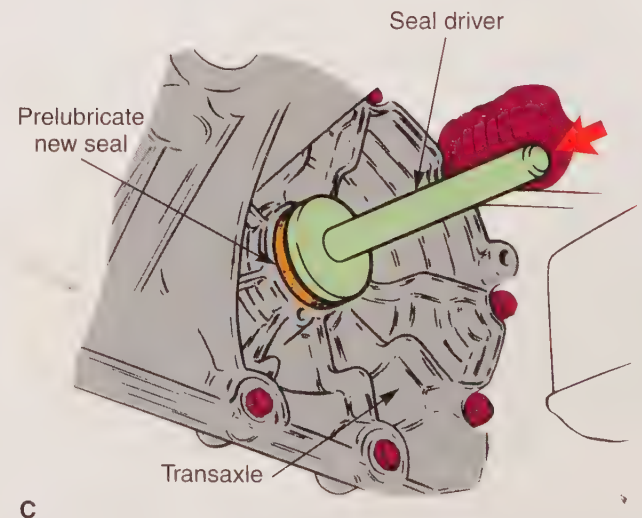
To replace some wheel hub and bearing assemblies, the steering knuckle must be removed from the vehicle. The knuckle is removed by separating it from the upper ball joint and the strut rod assembly. After reinstalling the knuckle, the front end of the vehicle must be aligned.



A



B



C

Figure 15-16. This series of steps illustrates one method of replacing a transaxle seal. (Ford)

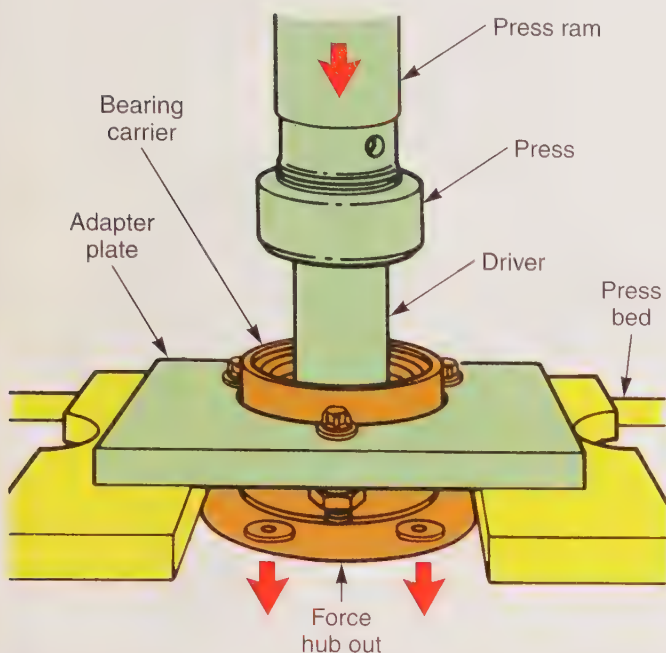


Figure 15-17. Some pressed-on bearings must be removed with a hydraulic press, driver, and the proper adapters. Never use excessive pressure on the housing or hub, as this can cause them to break. (Chrysler)

In some cases, the bearing carrier or the steering knuckle uses a seal that must be pressed from the knuckle or carrier housing before the bearing can be removed, **Figure 15-18**. Once the seal is removed, the bearing can be pressed out of the housing, **Figure 15-19**.

Some CV axle assemblies are pressed into the steering knuckle or carrier. In these cases, the shaft must be

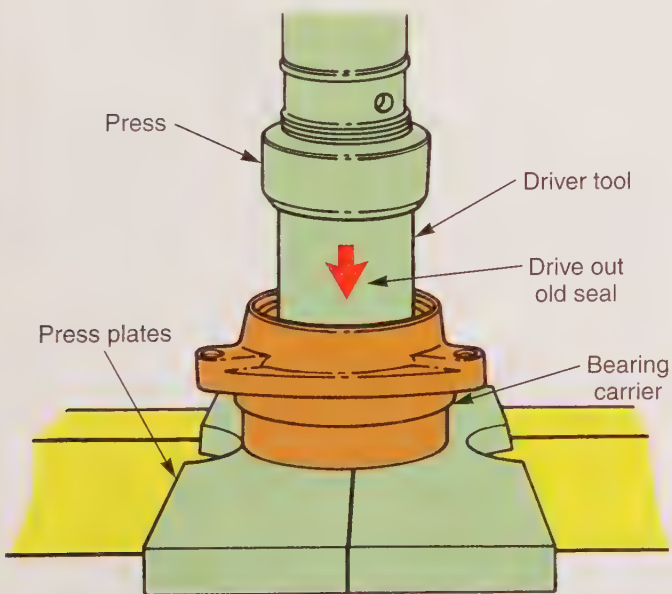


Figure 15-18. Some seals must be removed using a hydraulic press, driver, and suitable adapters. Other seals are held in place by clips. A few seals will be pressed out when the bearing is removed. (Chrysler)

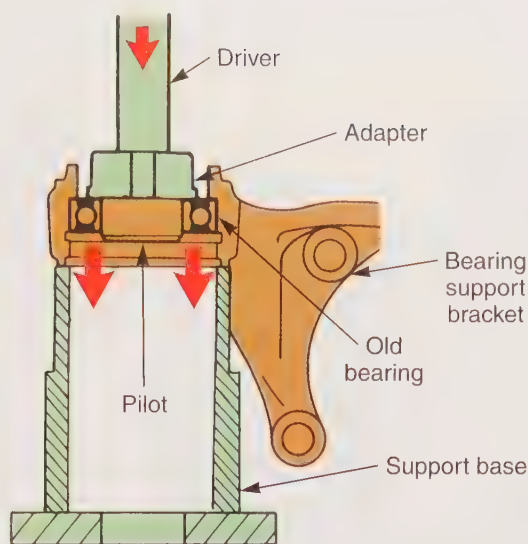


Figure 15-19. Bearings must be carefully removed. A hydraulic press, with a driver and the proper adapter, is often used to remove bearings. Always consult the service manual for exact procedures. (Honda)

removed from the knuckle or carrier housing with the proper puller. See **Figure 15-20**. After the shaft is removed, the outboard bearing can be removed from the housing.

If tapered roller bearings are used, the bearing races must be replaced when the bearings are replaced. **Figure 15-21** shows a driver being used to remove bearing races from a typical housing.

Some bearings are pressed into the housing with a spacer between them to maintain proper bearing position. If you replace the bearings or the housing in this type of system, you must select the proper replacement spacer or bearing problems will result. A few systems use a collapsible spacer, similar to the collapsible spacer used in rear-wheel drive pinions. Refer to the manufacturer's service manual for exact replacement procedures.

Install new bearings, races, and seals with the proper driver and a hydraulic press. See Chapter 4 for more

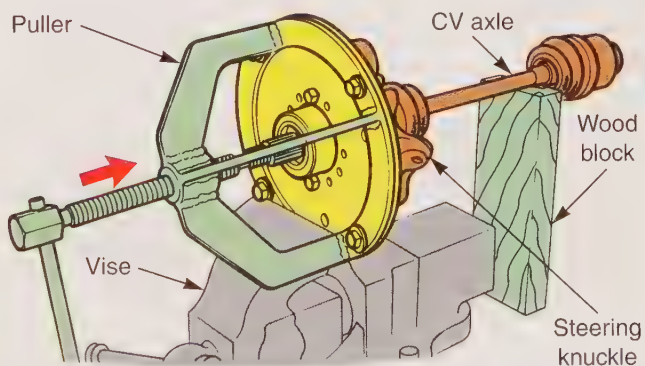


Figure 15-20. To gain access to some bearings, the CV axle and the steering knuckle assembly must be removed from the vehicle as a unit. The components are then separated with a puller. (Subaru)

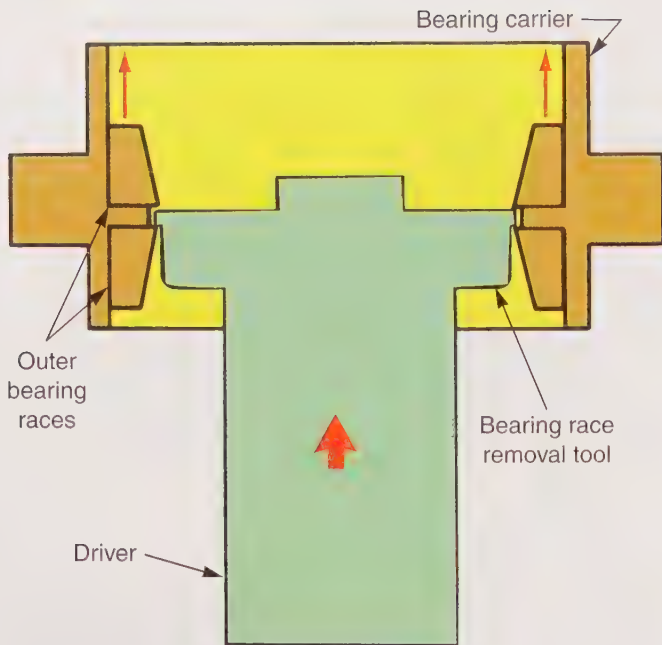


Figure 15-21. Special drivers are used to remove and install the outer bearing races used with tapered roller bearings. When using these drivers, be careful not to damage the seating surfaces in the housing. Races should not be removed unless new races are to be installed. (Chrysler)

information on bearing installation. **Figure 15-22** shows the adapters needed to service the ball bearing and seal on a common front-wheel drive vehicle.

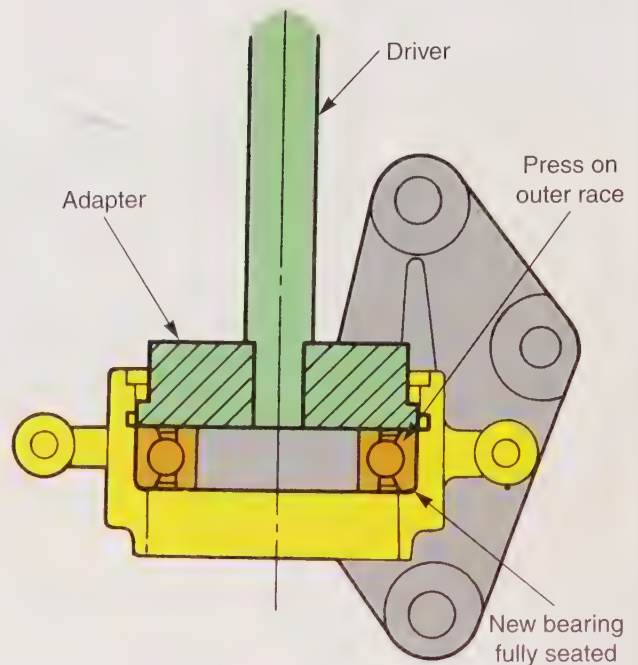
Tripod Joint Service

Tripod joints, such as the one shown in **Figure 15-23**, are often used as inboard joints and occasionally as outboard joints in CV axle assemblies. The ability of these joints to compensate for changes in the effective distance between the transaxle and the wheel hub while allowing the axle assembly to flex makes them popular.

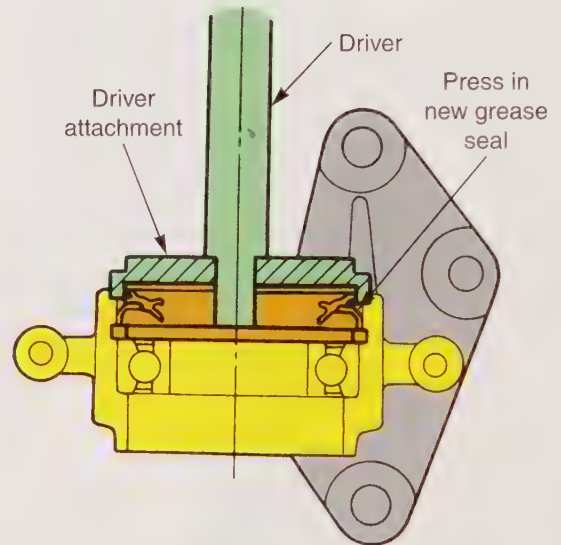
The service techniques for most tripod joints are similar. However, you may have to choose between rebuilding and replacing the joint. See **Figure 15-24**. In some cases, a joint may be damaged so badly that it is easier and cheaper to replace it. Some tripod joints cannot be rebuilt.

Following are the general procedures for rebuilding a tripod joint. Always refer to the proper service information for specific instructions.

1. To begin tripod joint service, clamp the CV axle shaft in a vise. Be careful not to damage the shaft by over-tightening the vise jaws.
2. Remove the boot clamps, and then pull the boot away from the tripod joint, **Figure 15-25**.
3. Remove any grease that prevents a clear view of the internal parts of the joint.
4. Separate the tripod and outer housing. Remove any retaining clips or tabs as detailed in the service manual.



A



B

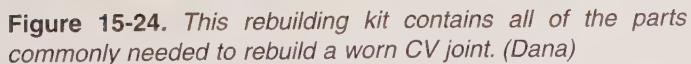
Figure 15-22. This figure illustrates the installation of a new bearing and seal in a steering knuckle housing. A—Installing the new bearing with a special adapter. B—Installing the new seal. (Honda)

5. Paint alignment marks on the tripod spider and the shaft to ease reassembly, **Figure 15-26**, and then, remove the spider from the shaft, **Figure 15-27**.
6. Clean the spider assembly, and then inspect the components for wear and damage. Pay particular attention to the needle bearings, the wear surface between the rollers and the housing, and the snap rings that hold the assembly together.
7. Replace worn parts as needed or replace the entire assembly with a new or rebuilt unit.
8. To reassemble the tripod joint, install a small boot clamp on the axle shaft. Then install a new boot on



rebuilding kit. Most replacement joints have grease already packed into the housing. Any extra grease should be placed inside the boot to provide additional lubrication.

-
- A**
- Pry off with screwdriver
- Small boot clamp
- B**
- Pry off or twist open
- Large boot clamp



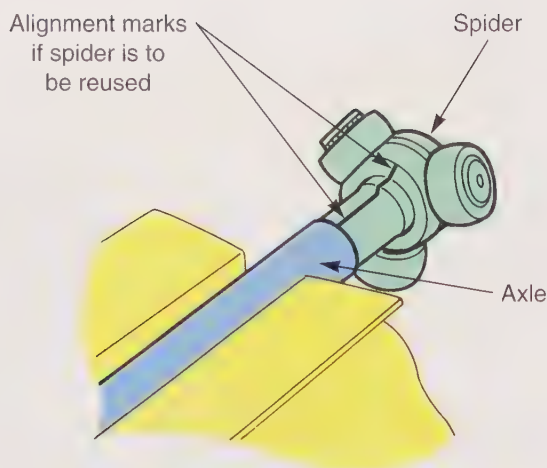


Figure 15-26. Always make alignment marks if the tripod spider will be reused. This ensures the spider will be reinstalled correctly.

11. Install the rollers on the spider, and then slide the spider into the housing. Some spiders must be pressed or driven into the housing. If the spider must be installed in this way, tape the rollers to prevent them from falling off during installation. See **Figure 15-28**. The tape can be removed just before the rollers enter the housing. Grease all moving surfaces as recommended by the manufacturer. Make sure the retaining snap rings and tabs are in good condition and can hold the tripod in the housing.
12. Once the spider assembly is installed in the housing, install the boot flanges into the boot retaining grooves in the housing and then clamp the boot in place. Check the joint for free rotation at various angles.

Ball-and-Cage Joint Service

Ball-and-cage joints, such as the one shown in **Figure 15-29**, are the most popular type of CV joint. At least one ball-and-cage joint will be found on most CV axle shafts. Some ball-and-cage joints cannot be serviced, and the entire assembly must be replaced. If the CV joint can be serviced, consult the manufacturer's service information for exact procedures. The following is a *general* guide to rebuilding ball-and-cage joints.

1. To rebuild a typical ball-and-cage joint, lightly clamp the CV axle shaft in a vise.
2. Remove the boot clamps and pull the boot away from the joint.
3. Clean off any grease that will prevent inspection and disassembly of the joint.

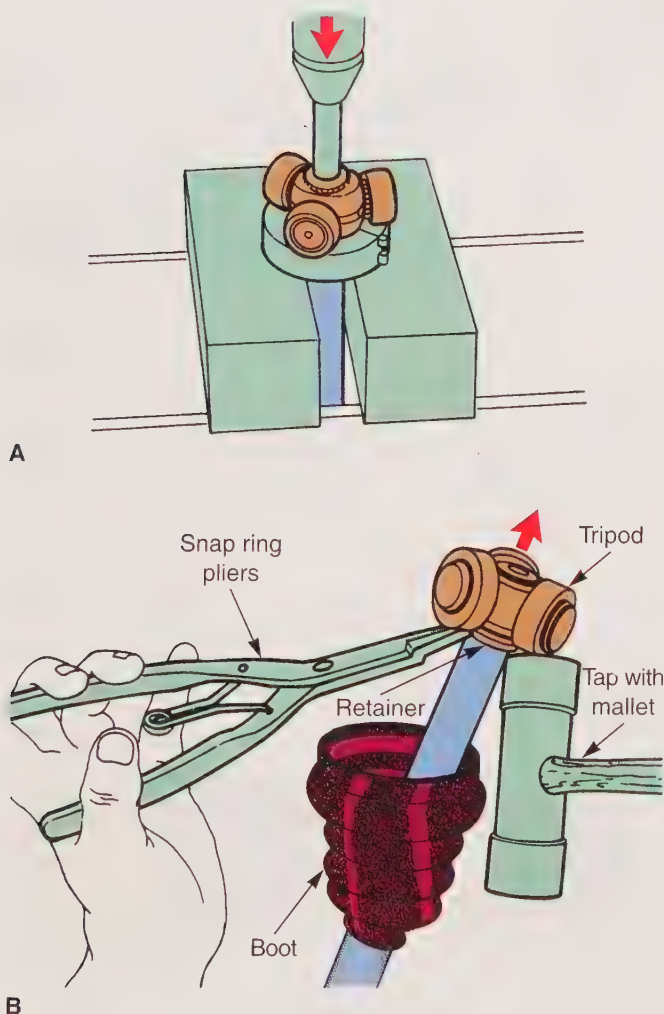


Figure 15-27. The tripod spider usually slides off the shaft, but not always. A—This tripod spider must be pressed off its shaft. B—Snap ring pliers and a mallet are used to remove this spider. (Chrysler)

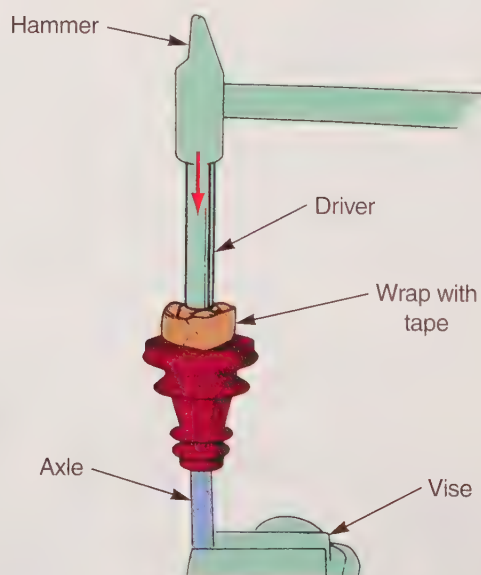
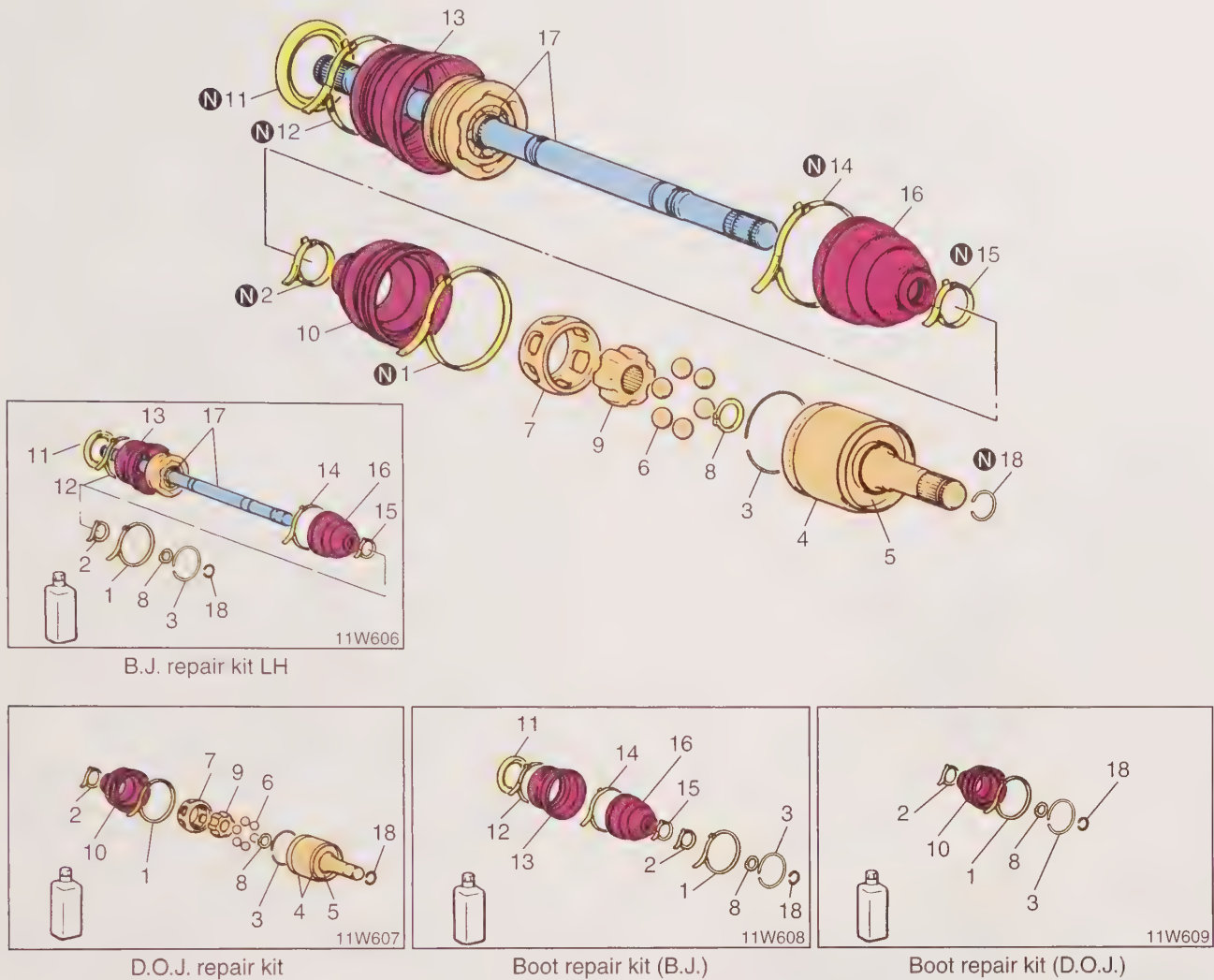


Figure 15-28. Before installing the new spider assembly in the housing, wrap the assembly with tape to keep it from coming apart. The tape can be removed just before the spider assembly enters the housing. (Chrysler)

**Disassembly steps**

1. Boot clamp A
2. Boot clamp B
3. Circlip
4. D.O.J. outer race
- ↔ 5. Dust cover
- ↔ 6. Balls
- ↔ 7. D.O.J. cage
- ↔ 8. Snap ring
9. D.O.J. inner race
- ↔ 10. D.O.J. boot
- ↔ 11. Dust cover
- ↔ 12. Boot protector band
- ↔ 13. Boot protector
14. Boot clamp A
15. Boot clamp B
- ↔ 16. B.J. boot
17. Drive shaft and B.J.
18. Circlip

Reassembly steps

17. Drive shaft and B.J.
- ↔↔ 16. B.J. boot
- ↔↔ 14. Boot clamp A
- ↔↔ 15. Boot clamp B
- ↔↔ 2. Boot clamp B
- ↔↔ 10. D.O.J. boot
- ↔↔ 1. Boot clamp A
- ↔↔ 7. D.O.J. cage
- ↔↔ 9. D.O.J. inner race
8. Snap ring
- ↔↔ 6. Balls
- ↔↔ 5. Dust cover
- ↔↔ 4. D.O.J. outer race
3. Circlip
18. Circlip
- ↔↔ 13. Boot protector
- ↔↔ 12. Boot protector band
- ↔↔ 11. Dust cover

Note

- (1) ↔ : Refer to "Service Points of Disassembly".
- (2) ↔↔ : Refer to "Service Points of Reassembly".

- (3) **N** : Nonreusable parts
- (4) B.J. : Birfield joint
- (5) D.O.J. : Double offset joint

Figure 15-29. General procedure given here shows the typical sequence followed for disassembly and reassembly of a CV axle. The ball-and-cage joint shown here is at the outboard end of the axle. Note the repair kits that are available. (General Motors)

4. Before disassembling the ball-and-cage joint, place alignment marks on the joint housing and the axle shaft to ensure that all parts are reassembled in their original position, **Figure 15-30**.
5. Remove any snap rings that hold the joint together. Figure 15-30 shows typical snap ring locations. Actual snap ring locations vary, and a few CV joints do not have snap rings. Always check the appropriate service literature for snap ring locations before attempting to force the joint apart.
6. After the snap rings are removed, remove the joint housing or the axle shaft from the ball-and-cage assembly. The part that is removed will vary, depending on the design of the joint. If the ball-and-cage assembly is still inside the housing (this will be the case with most joints), carefully tilt the cage in the

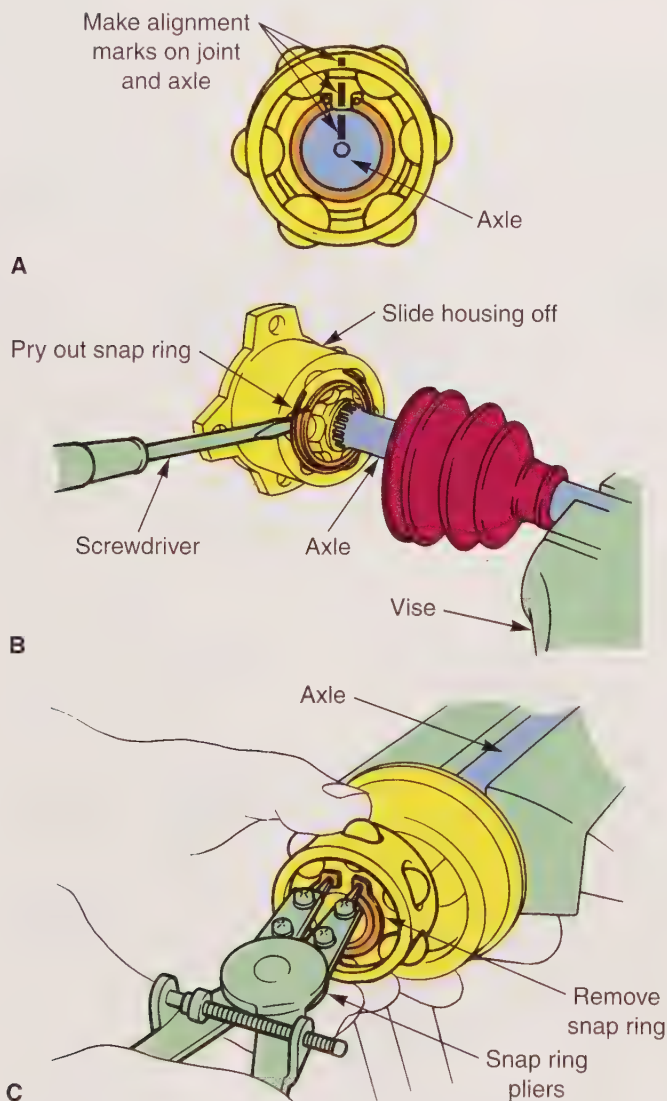


Figure 15-30. To begin disassembly of a ball-and-cage joint: **A**—Mark the shaft and housing for proper reassembly. **B**—Remove the internal snap ring that holds the cage in the housing. **C**—Remove the external snap ring holding the shaft to the inner cross.

housing by pressing down on one side of the cage. You can then remove the ball from the opposite side of the cage. Repeat this procedure until all the balls have been removed. During disassembly, place the balls so that they can be reinstalled in the raceways from which they were removed.

7. Once the balls have been removed, the cage and inner cross assembly can be turned sideways and removed from the housing.
8. After the assembly has been removed from the housing, the inner cross can be removed from the cage. The CV joint is now completely disassembled. **Figure 15-31** shows the sequence of events for disassembling a typical ball-and-cage joint.
9. After the joint is completely disassembled, clean all the parts and inspect them for wear. The housing and inner raceways should be checked carefully for excessive wear and scoring. Check the balls for pitting, cracks, score marks, and uneven wear. Also study the ball cage for wear or cracks. Check the lubricant for contamination. Defective parts should be replaced. In some cases, the entire joint must be replaced.
10. To reassemble a ball-and-cage joint, align the parts and install the inner cross into the cage.
11. Then, install the cage assembly in the housing. Tilt the cage to replace the balls. Make sure the balls are returned to the slots from which they were removed.
12. Install the boot and the joint housing on the axle shaft.
13. Reinstall the snap rings as necessary. See **Figure 15-32**.
14. After reassembly, thoroughly grease the joint. Place extra grease in the boot to provide additional lubrication, **Figure 15-33**.
15. Install the boot over the joint, and then tighten the boot clamps, **Figure 15-34**.
16. Check the joint for free rotation at various angles. To ensure the joint has been properly reassembled, some manufacturers recommend checking the length of the joint between the boot clamps, **Figure 15-35**.

CV Joint Boot Service

The CV joint boots retain lubricant and protect the CV joint from water and dirt. The boots should be inspected whenever the technician is under the vehicle. Look for grease on the underside of the vehicle near the boot. This may indicate a punctured boot that is throwing grease as it rotates. Another cause of leakage is a clamp that is broken or loose. A leaking boot should be serviced immediately to prevent joint failure.

When working on CV axles, make sure you do not damage the boots. When reinstalling a boot, remove any kinks from the boot bellows and position the clamps properly. Do not overtighten the clamps. To prevent damage, do not rotate the CV joints at abnormal angles when they are removed from the vehicle.

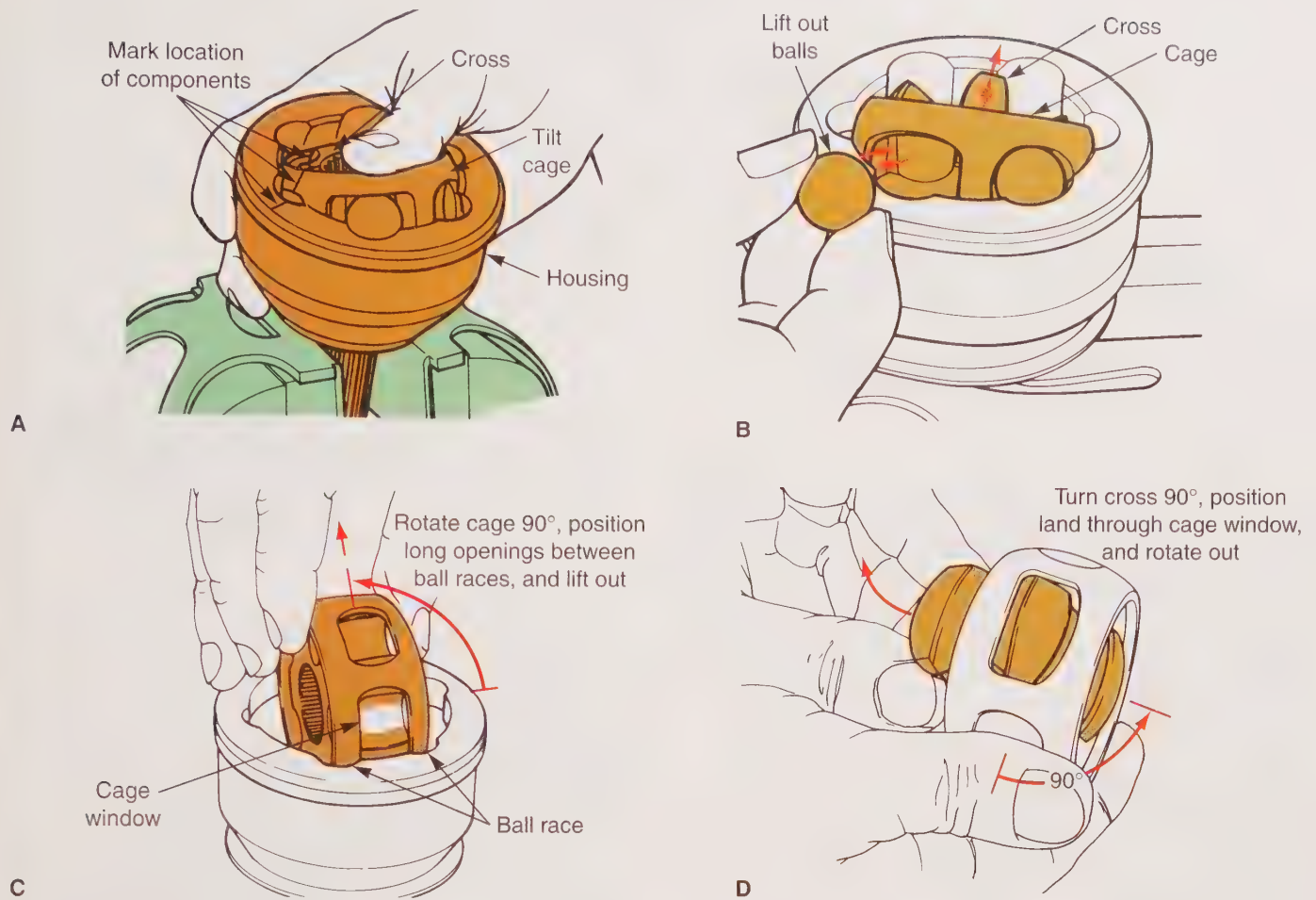


Figure 15-31. Disassembly sequence for a common type of ball-and-cage joint. A—Place the joint in a vise, mark the relative location of components, and press down on one side of the cage. This will tilt the other side of the cage upward. B—Lift out the ball on the raised side of the cage. It may be necessary to force the ball out with a small screwdriver. Repeat these steps until all the balls are removed. C—Turn the cage at a 90° angle to the housing and lift it out of the housing. D—Remove the inner cross from the cage. The CV joint is now completely disassembled. (Chrysler)

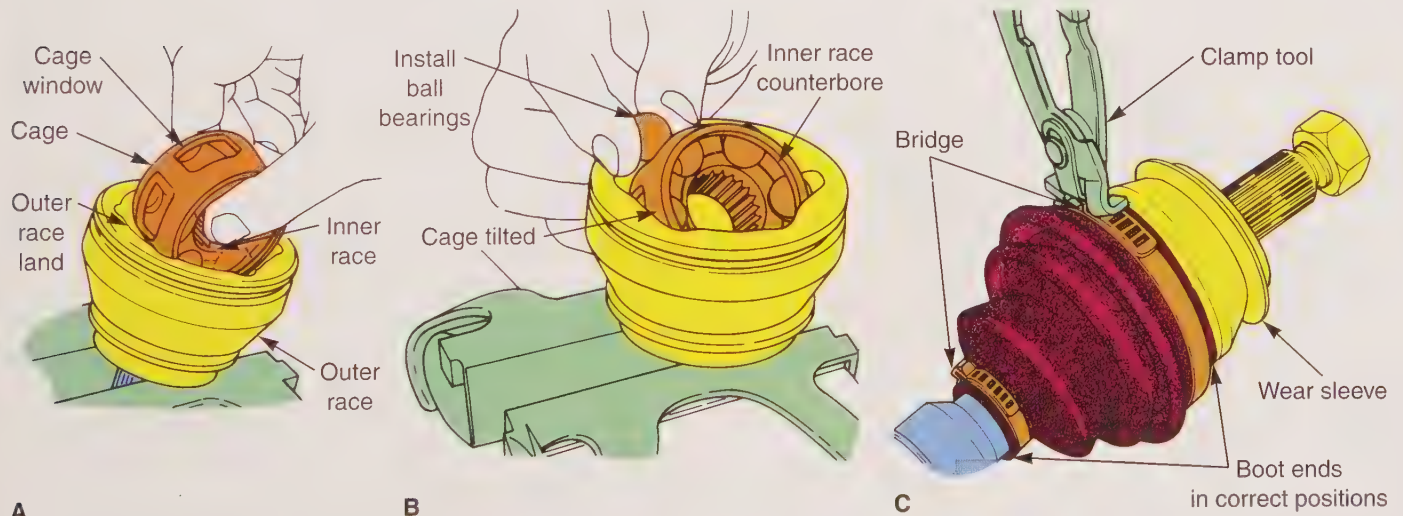


Figure 15-32. Reassembling the ball-and-cage joint. A—Place the cage and the inner cross back in the housing. B—Reinstall the balls. C—After installing snap rings and other necessary parts, fit the boot over the joint and install the boot clamps. (Ford, Chrysler)

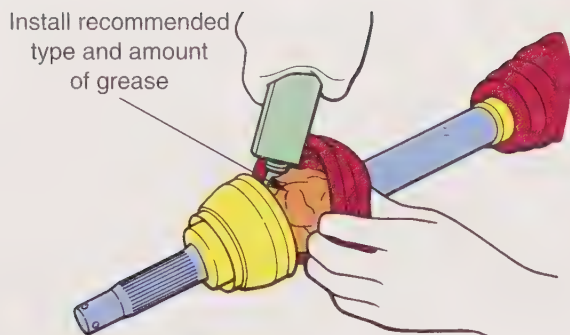
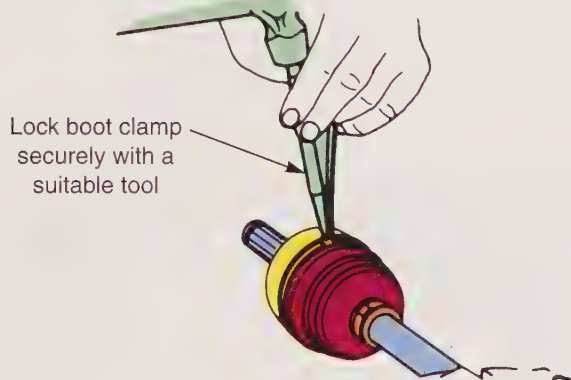


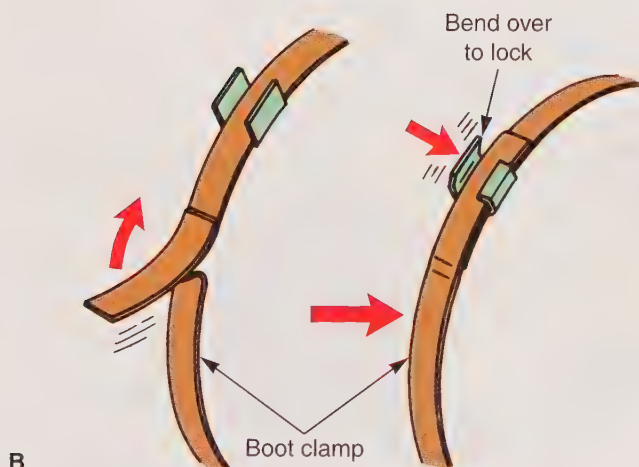
Figure 15-33. Be sure to install the proper amount of CV joint lubricant before reinstalling the boot and clamps. (General Motors)

Unless you are working with a new vehicle, it is best to install new boots whenever they are removed. Although boots are inexpensive, installation is time consuming. Boot removal procedures were covered earlier in this chapter.

Some replacement CV joint boots can be installed without removing the CV axle from the vehicle. These boots are split to permit assembly over the axle shaft and



A



B

Figure 15-34. The boot clamps must be installed carefully. A—A punch and hammer are used to lock the retaining tabs over the clamp. B—This figure shows the proper method of securing the clamp. (General Motors)

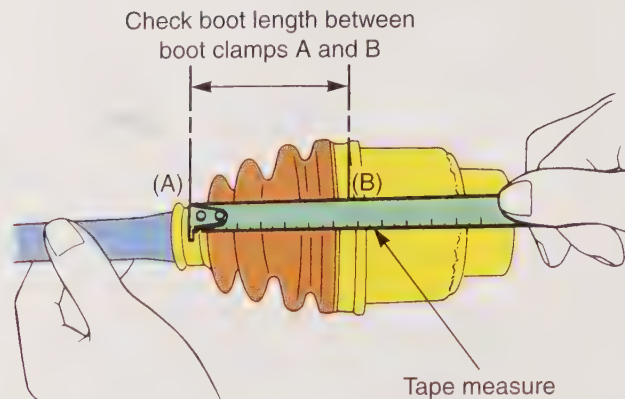


Figure 15-35. To ensure the CV joint has been reassembled properly, some manufacturers recommend checking the installed length of the boot. (General Motors)

the joint. Most boots, however, can only be replaced by removing the CV axle.

The boot replacement procedure presented here should be used as a general guide. Always consult the manufacturer's service information before replacing a boot.



Note: The following procedure assumes the axle shaft and the CV joint have already been disassembled.

If a boot is secured by one-piece clamps, slide the small clamp onto the axle shaft before installing the boot. Then slide the small end of the boot over the axle shaft and position it as necessary. If the shaft is splined, protect the boot by placing tape over the splines. Place the boot flange into the groove on the shaft. Position the clamp over the groove and make sure the clamp and boot are properly aligned.

Several types of clamps are used on CV joint boots. Some manufacturers use **metal ladder clamps**, which are similar to cooling system hose clamps. Other manufacturers use **rubber rings** or **metal spring clamps** to hold the boots in place. A common type of clamp is the **strap-and-buckle clamp**, **Figure 15-36**. A special tool must be used to install this clamp. It is important to avoid overtightening the clamps. Overtightening will damage the boot and cause a leak.

After installing the small clamp, fill the boot with grease as recommended by the manufacturer. Then, reassemble the CV joint.

With the joint reassembled, place the flange at the large end of the boot in the corresponding groove in the CV joint housing. Make sure that all parts are aligned properly and that the boot will not be twisted when the clamp is installed. Finally, install the large boot clamp in the same manner as the small clamp.

If the boot has wrinkled or kinked sections, smooth them out by pulling outward on both sides of the wrinkle. See **Figure 15-37**.

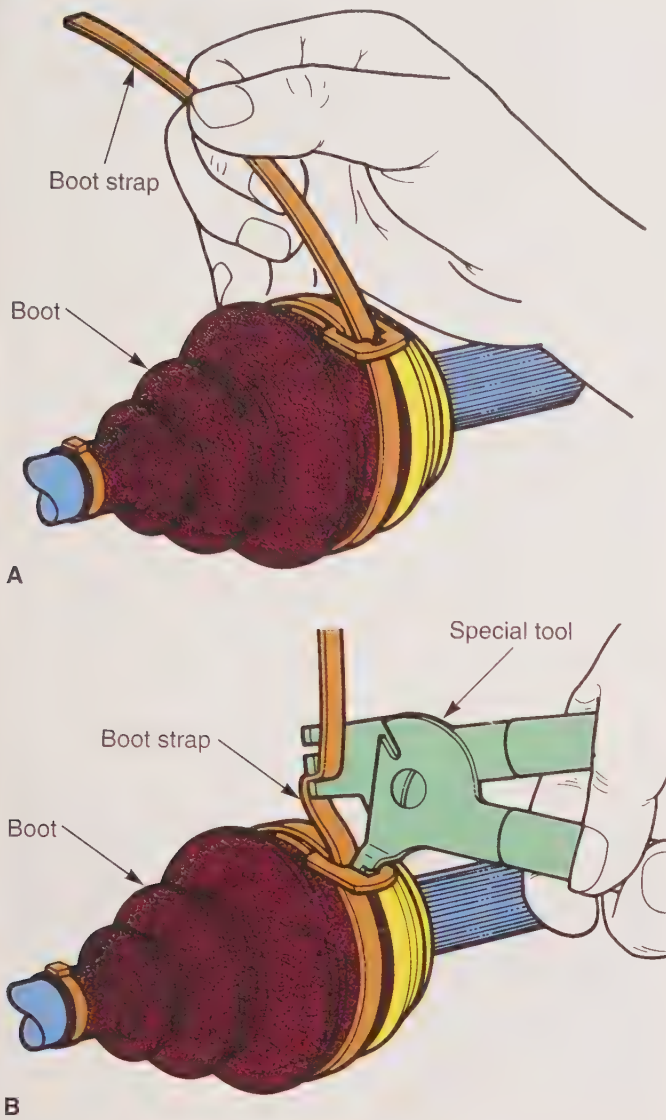


Figure 15-36. Installing a strap-and-buckle boot clamp requires the use of a special tool. A—Install strap on boot. B—Use tool to tighten the strap on the boot. (Chrysler)

CV Axle Installation

The CV axle shaft is installed in a vehicle in the reverse order of removal. The procedure outlined here will apply to most vehicles. Always consult the factory service information for specific installation instructions.

1. In systems where the axle shaft yoke enters the transaxle directly, lightly oil the outer surface of the shaft. Hold the inner CV joint assembly at the housing while guiding the shaft into the transaxle.
2. If the inner shaft is held in the differential by a circlip, install the clip after the axle is positioned in the transaxle. Replace the differential cover using a new gasket. If the speedometer drive gear was removed from the transaxle, it should be reinstalled at this time. If necessary, refill the transaxle with the proper type and grade of lubricant. Do not reuse fluid that has been drained from the transaxle.

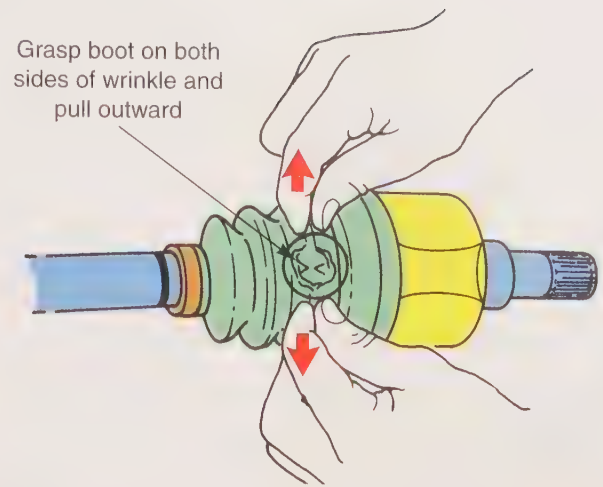


Figure 15-37. Wrinkles and kinks can be removed from the CV joint boot by pulling away from the wrinkle on both sides of the boot. Never install a CV axle with a kinked boot. A kinked boot will develop a split and begin leaking. (Ford)

If bolts are used to secure the axle to the transaxle output shaft, align the axle with the output shaft flange and install the bolts that hold the axle to the flange.

3. After securing the axle in the transaxle, install the outer CV axle shaft in the steering knuckle assembly. Then, reinstall the knuckle on the ball joint stud and the MacPherson strut assembly. Finally, reinstall the tie rod end on the knuckle and tighten the attaching nuts or bolts. Be sure to use new cotter pins where needed.
4. Reinstall the front wheel bearing, the adjusting nut, and related washers or other parts. Torque the adjusting nut to the proper specifications, **Figure 15-38**. After adjusting the nut to get the proper preload, stake the nut to the stub shaft or install a new cotter pin to keep the nut from backing off. See **Figure 15-39**.

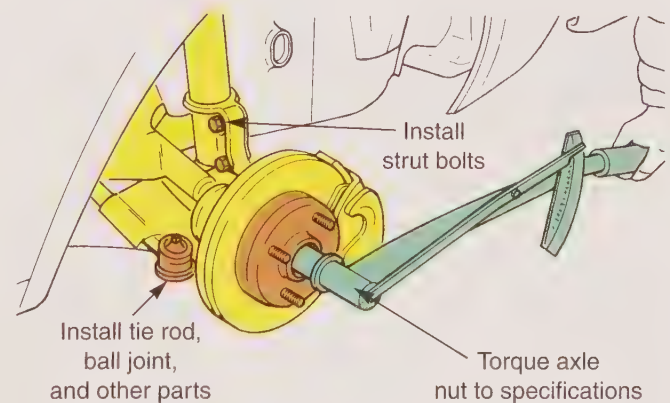


Figure 15-38. After the CV axle is installed, install the steering knuckle attachments and torque the axle nut to the specifications. (Chrysler)

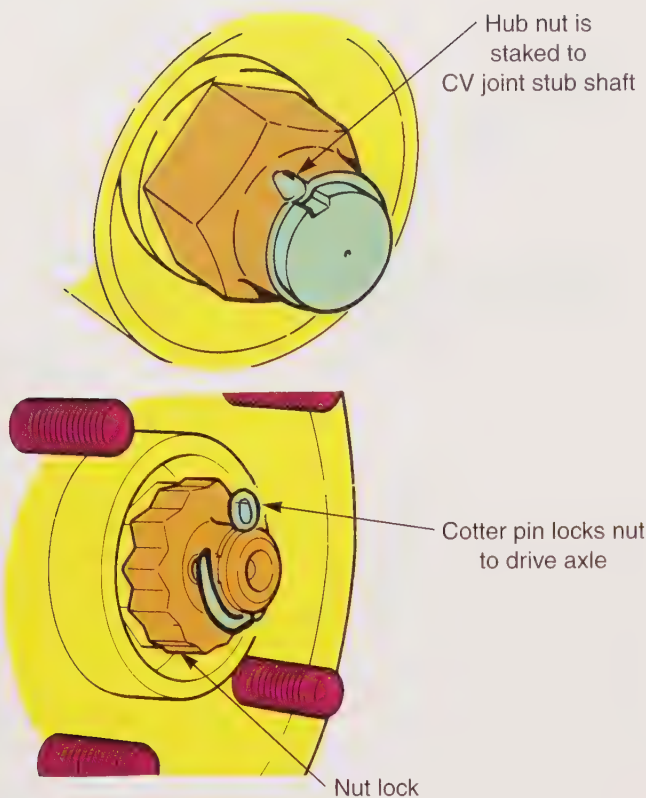
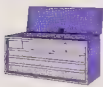


Figure 15-39. Always make sure the spindle nut cannot work loose. Some nuts are staked to the shaft, but most use a cotter pin and a nut lock. (Ford, Chrysler)

5. After installation, make sure the shaft rotates freely and the CV joint boots are not kinked or collapsed. If necessary, rework the boot to remove kinks and wrinkles. In some cases, it may be necessary to loosen a boot clamp to allow air to enter a collapsed joint boot.
6. After the CV axle is installed properly, reinstall the wheel on the hub.
7. Lower the vehicle.
8. Reconnect the battery negative cable and conduct a road test.



Note: On some vehicles, the front end alignment must be checked if the steering knuckle has been disassembled.

Summary

CV axles are simple devices, but they can develop problems. CV axle problems can be grouped into three areas: noises, vibrations, and leaks. These problems are generally caused by defective CV joints, wheel bearings, or joint boots. Before working on a CV axle, always make sure the problem is not caused by a malfunction in some other part of the vehicle. It may be necessary to put the

vehicle on a lift or to perform a road test to determine the exact cause of a problem.

The CV axle must be removed from the vehicle to make most axle repairs. In many cases, the axle must be removed to repair the transaxle or remove the engine.

To begin axle removal, raise the vehicle and remove the wheel from the side being serviced. Disconnect the front steering knuckle from the suspension components and pull the steering knuckle from the CV axle. The axle can then be removed from the transaxle. In some cases, the axle and knuckle must be removed from the vehicle as a unit.

After removal, be careful not to force the CV joints into extreme angles. Once the axle is on a clean workbench, the axle shafts should be checked for straightness, if necessary, the transaxle seals can be replaced after the axles are removed.

The wheel bearings should be checked and, if necessary, replaced. There are many bearing types and attachment methods. The technician must follow factory procedures when replacing wheel bearings.

Tripod joints are often used on CV axle shafts. To disassemble the joints, remove the boot and the retaining clips. The joint will then come apart easily. The tripod spider assembly should be checked for wear and replaced if needed. After reassembly, check the joint for proper flexibility and rotation. If the tripod joint is badly worn, it may be easier to replace the joint than to rebuild it.

The ball-and-cage joint is commonly used on CV axles. After the boot is removed, remove the retainer clips and disassemble the joint. The balls, raceways, and cage should be carefully checked for wear or corrosion. After the necessary new parts are installed, the ball-and-cage joint can be reassembled.

The CV joint boots are critical to the durability of the CV joints. If a boot is damaged, lubricant will be lost. In addition, dirt and water can enter the joint through a damaged boot. Damaged boots must be replaced promptly.

A CV axle is reinstalled in the reverse order of removal. The axle is installed in the transaxle assembly and reattached to the front steering knuckle and bearing assembly. Make sure all steering and suspension parts are reattached and the spindle nut is properly torqued and locked in place.

Review Questions—Chapter 15

Answer the following questions using the information provided in this chapter.

1. Describe the three categories of CV axle problems.
2. What is one of the most common causes of CV axle noise?
3. Rumbling or roaring noises that increase and decrease only slightly with vehicle speed are usually caused by bad _____.

4. Summarize four safety precautions that should be followed when working with CV axles.
 5. Since there are many design variations, what should you do when in doubt about a CV axle service procedure?
 6. What can happen if you use engine power to drive the front wheels with the front suspension and drive axles unsupported?
 7. What should you do if you suspect an axle shaft is bent?
 8. The ability of _____ joints to compensate for changes in the effective distance between the transaxle and the wheel hub while allowing the axle assembly to flex makes them popular.
 9. In your own words, explain how to service a tripod joint.
 10. In your own words, explain the service procedure for a ball-and-cage joint.
 11. Why should you install new boots during CV axle service?
 12. Explain the procedure for installing CV axles.
4. When a CV joint boot is squeezed, air is heard escaping. Technician A says that the boot is torn or a boot clamp is defective. Technician B says that the boot vent is working normally. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
 5. Technician A says that the CV axles must be removed from the transaxle before removing the transaxle from the vehicle. Technician B says that CV axles must always be removed from the wheel hub and bearing assemblies before removing the transaxle. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
 6. A new CV joint boot is being installed on a CV axle. Technician A says that some replacement boots can be installed without removing the CV axle. Technician B says that the boot clamps can be removed with a screwdriver. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.

ASE-Type Questions—Chapter 15

1. A CV axle is making a clicking noise. One of the CV joint boots is torn. Technician A says that the noise could be caused by a worn CV joint. Technician B says that regreasing the CV joint could eliminate the noise. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.
2. Each of the following abnormal noises is typical of those coming from a dry CV joint *except*:
(A) popping.
(B) clicking.
(C) snapping.
(D) rumbling.
3. CV axle vibrations can be caused by each of the following *except*:
(A) loose boot clamps.
(B) worn joints.
(C) a bent axle.
(D) loose axle attaching bolts.
7. Each of the following statements about servicing pressed-in wheel bearings is true *except*:
(A) the CV axle shaft must be pressed from the wheel hub.
(B) many wheel bearings are pressed into the bearing carrier or the steering knuckle, and the wheel hub is pressed into the bearing.
(C) if tapered roller bearings are used, the bearing races must be replaced when the bearings are replaced.
(D) some bearing assemblies require installation of a collapsible spacer.
8. Technician A says that tripod joints are the most common type of universal joint found on CV axles. Technician B says that tripod joints, when used, almost always serve as the inner CV joint. Who is right?
(A) A only.
(B) B only.
(C) Both A and B.
(D) Neither A nor B.

9. When replacing a CV joint boot, which of the following should be placed on the CV axle shaft first?
- (A) CV joint.
 - (B) Large boot clamp.
 - (C) Small boot clamp.
 - (D) Lubricating grease.
10. Each of the following could occur if a CV joint boot is improperly installed *except*:
- (A) rapid wear of the CV joint.
 - (B) CV joint noises.
 - (C) loss of lubricant.
 - (D) transaxle failure.
11. Technician A says that on some vehicles, the front-end alignment must be checked after the wheel bearings are serviced. Technician B says that some stub shaft nuts are held in place by a cotter pin. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.



Chapter 16

Rear Axle Assembly Construction and Operation

After studying this chapter, you will be able to:

- ☐ Explain the purpose of a rear axle assembly.
- ☐ Identify the major parts of a rear axle assembly.
- ☐ Describe the differential drive gears and related parts.
- ☐ Calculate rear axle ratio.
- ☐ Compare differential and rear axle assembly design variations.
- ☐ Describe the operation of a standard differential and of the various types of locking differentials.

Technical Terms

Solid-axle rear suspension	Spider gears	Pinion pilot bearing
Independent rear suspension	Side gears	Side bearings
Differential drive gears	Locking differential	Integral carrier
Drive pinion gear	Limited-slip differential	Solid drive axle
Pinion bearing	Clutch-plate differential	Axle flange
Collapsible spacer	Cone differential	Axle bearing
Jam nut	Ratchet differential	Axle collar
Pinion shim	Torsen differential	Axle retainer plate
Ring gear	Hydraulic locking differential	Semi-floating axle
Wheel hop	Differential carrier	Axle shim
Standard differential	Axle tube	Full-floating axle
Differential case	Removable carrier	Independently suspended drive axle

Introduction

The rear axle assembly is used on rear-wheel drive vehicles. This assembly is the final leg of the drive train. It is often called the final drive or rear end. The rear axle assembly is often mistakenly called the differential. The differential is only part of the rear axle assembly.

The basic design of rear axle assemblies has been adopted by all manufacturers for many years. There are several variations, but all operate according to the same basic principles. The major difference between rear axle assemblies depends on whether the vehicle has solid-axle rear suspension or independent rear suspension. **Solid-axle rear suspension** incorporates rigid and nonflexing drive axles and axle tubes; both wheels move as one solid unit in response to bumps and potholes. **Independent rear suspension** incorporates jointed drive axles (no axle tubes) that allow for flexibility and independent axle movement.

This chapter is designed to identify and explain the construction and operation of various rear axle assemblies. The material in this chapter provides a basis for understanding how to properly troubleshoot and repair rear axle assemblies.

Construction and Operation Overview

The rear axle assembly includes the differential assembly, the rear drive axles, and the rear axle housing. Rear axle assemblies are subjected to heavy loads from the

engine and road. They are ruggedly constructed and seldom fail. The most common rear end failures are axle bearing failures. A typical rear axle assembly is shown in **Figure 16-1**.

In a rear axle assembly, engine power enters the drive pinion gear from the drive shaft assembly and differential pinion yoke/flange. The drive pinion gear, which is in mesh with the ring gear, causes the ring gear to turn. The interaction of the ring and drive pinion gears turns the power flow at a 90° angle. The difference in the number of teeth on the ring and pinion gears causes a reduction gear ratio. This reduces turning speed, while increasing torque. Power from the ring gear flows through the differential case, spider gears, and side gears to the drive axles. The drive axles transfer power from the differential assembly to the rear wheels.

The bearings and rear axle housing are key components of the rear axle assembly. They are designed to support and align the differential assembly and the drive axles. Notice that the bearings and axle housing are large, heavy-duty parts. This is to ensure they will stand up under hard usage.

Seals and gaskets are also very important to the operation of the rear axle assembly. Seals are used at the differential pinion yoke/flange and at the outer drive axles. Gaskets are used at housing interfaces, such as between the differential cover and the housing, to provide a tight seal from the outside.

Figure 16-2 is an exploded view of a common type of rear axle assembly. Notice the relationship of the internal parts to the housing and to each other. Note that the rear

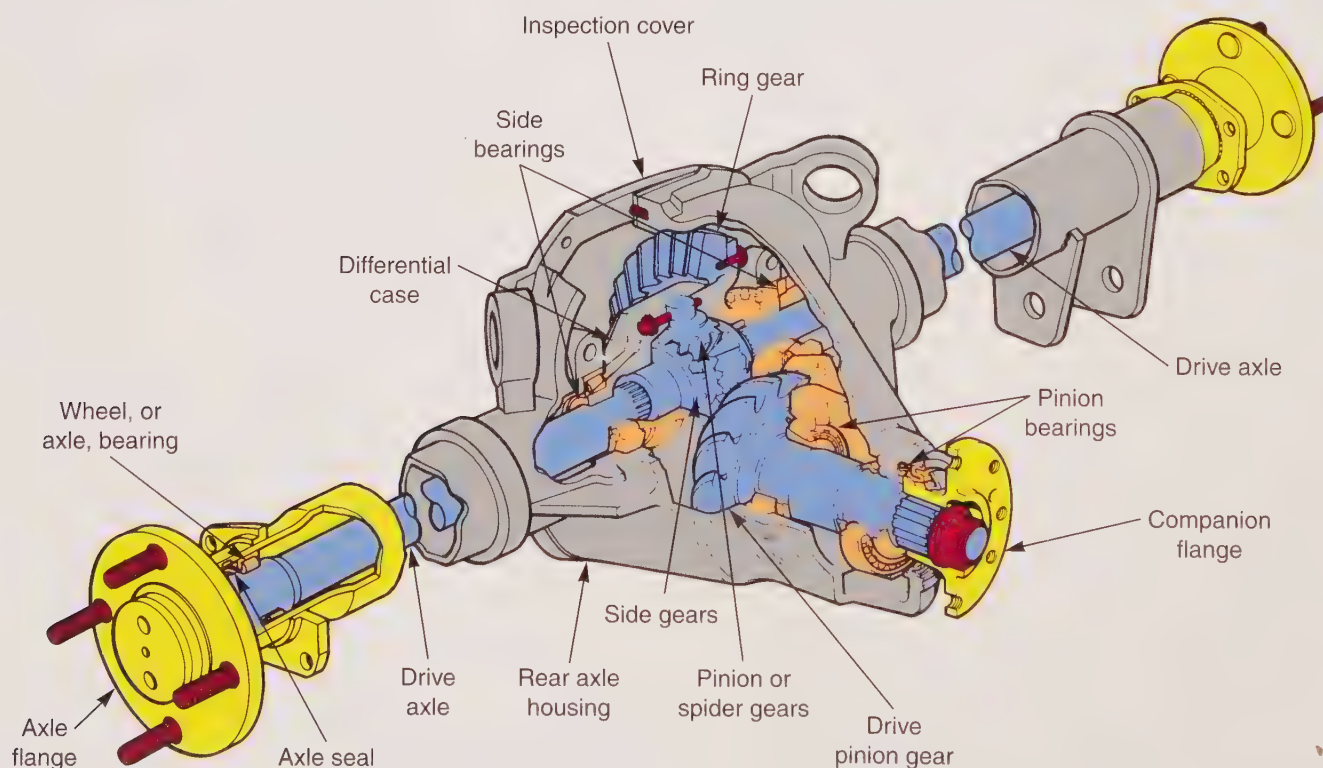


Figure 16-1. Most rear axle assemblies contain the same parts as shown in this cutaway. Note that some drive axles differ from this basic design. (Ford)

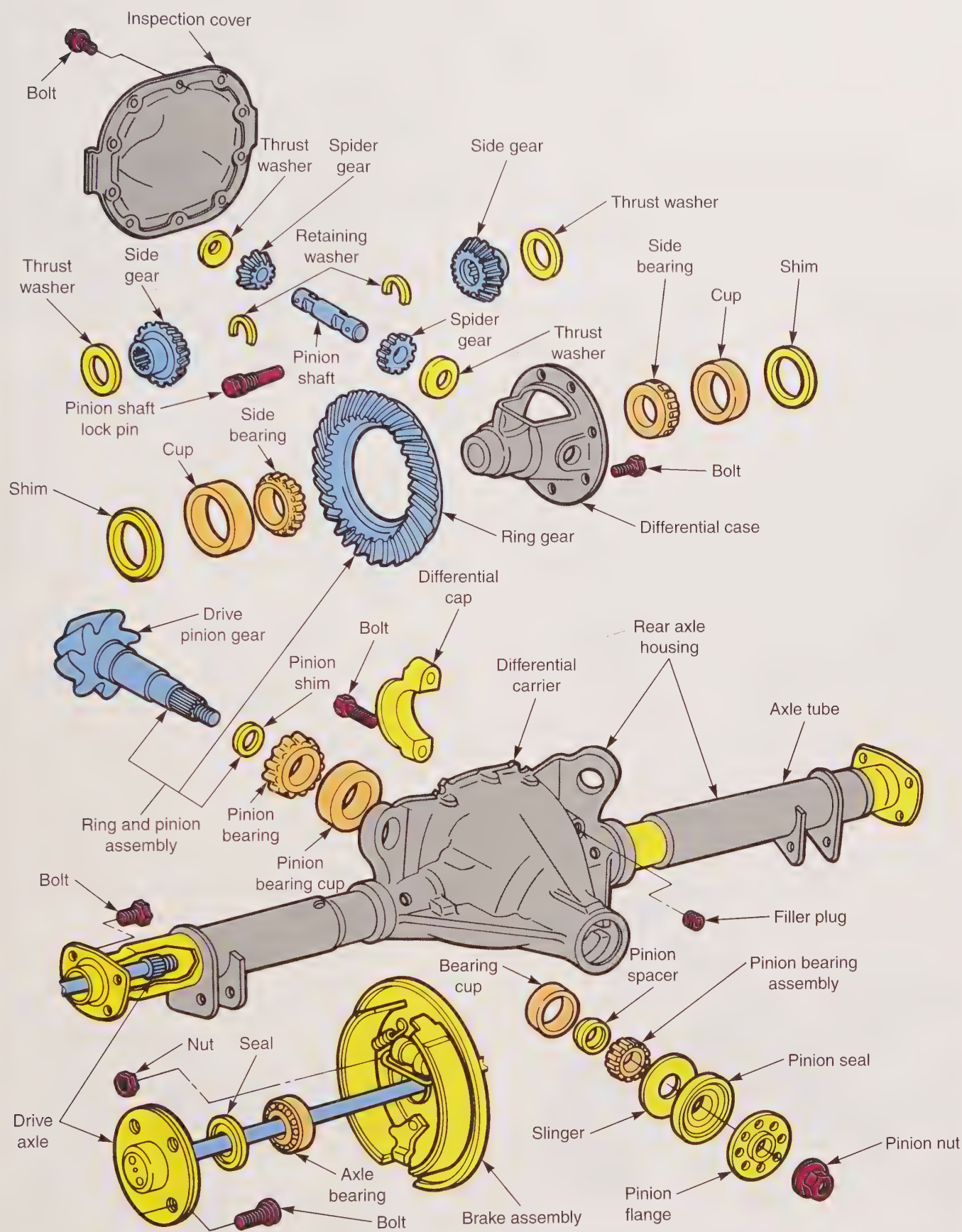


Figure 16-2. Exploded view of a rear axle assembly shown in Figure 16-1. (Ford)

axle housing and drive axle designs will be different when the vehicle has independent rear suspension. Also, when the rear axle assembly is equipped with a limited-slip differential, it will contain more parts. These features will be discussed later in this chapter.

Differential Assembly

The differential assembly in a rear-wheel drive vehicle has three functions. The first, and most obvious, is to redirect the power flow to drive the rear wheels. The power flow must make a 90° turn between the drive shaft assembly and the rear wheels. This is accomplished in the differential assembly by the drive pinion and ring gears.

The second function of the differential assembly is to multiply engine power, reducing speed at the output in the process. If there were no gear reduction (1:1 gear ratio), the vehicle would accelerate very slowly. In some cases, the engine would be unable to move the vehicle. At the very least, gas mileage would be harmed, since the engine would not reach its most efficient rpm range. For this reason, the ring and drive pinion assembly, by design, provides a reduced speed at its output. The reduction is between 2:1 and about 5:1, depending on the engine size, vehicle weight, and intended use of the vehicle.

The third function of the differential assembly is to allow the vehicle to make turns. If the assembly did not make allowances for the different speeds of the rear wheels during turns, one tire would lose traction with the ground as the vehicle turned corners. The differential assembly allows the vehicle to make smooth turns.

The differential assembly consists of numerous parts, including the differential drive gears (ring and drive pinion gears), pinion bearings, differential case, spider and side gears, and side bearings. See **Figure 16-3**. These parts and their function are described in detail in the following section.

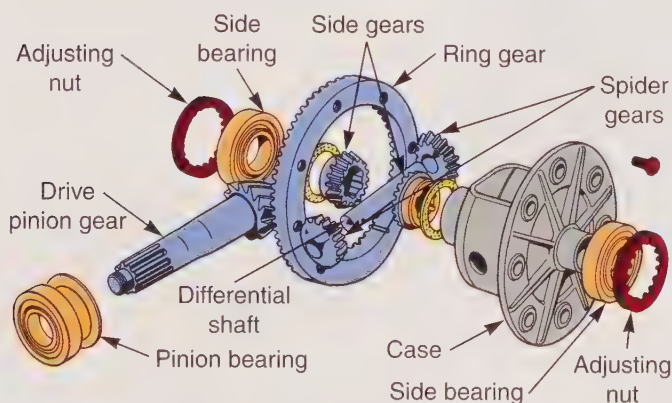


Figure 16-3. Relative positions of parts of a differential assembly. The interaction of the various parts of the differential may be more easily understood by studying this illustration. (Subaru)

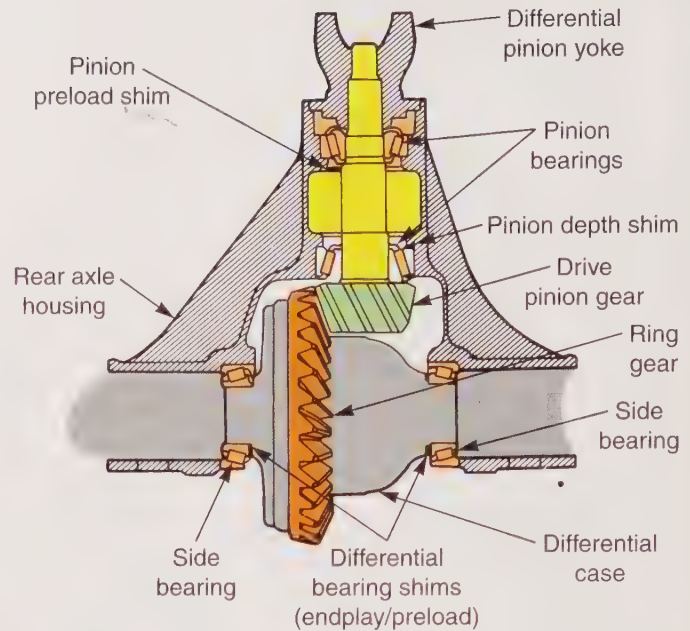


Figure 16-4. The positions of the drive pinion gear and the ring gear are always about the same. The two pinion bearings and two side bearings are always tapered roller bearings that must be carefully adjusted. Some drive pinion gears have a third bearing—a pinion pilot bearing—for support. Bearings and adjusting devices (shims or adjusting nuts) are usually located as shown. (Chrysler)

Differential Drive Gears

The **differential drive gears** also called the **ring and pinion gearset**, consist of the ring and drive pinion gears, **Figure 16-4**. These hypoid gears redirect power flow by 90° and multiply engine power. The number of teeth in the ring gear compared to the number of teeth in the drive pinion gear sets the rear axle ratio. For instance, if the ring gear has 40 teeth and the pinion gear has 10 teeth, the ratio is 40:10, or 4:1. The ring gear always has more teeth than the drive pinion gear. Rear axle ratios can always be determined by dividing the number of teeth on the ring gear by the number of teeth on the drive pinion gear.

Drive pinion gear

The **drive pinion gear** is a hardened-steel gear with an integral shaft, **Figure 16-5**. It is machined to mesh with and rotate the ring gear. The end of the shaft opposite the gear has external splines that fit the internal splines of the differential pinion yoke/flange. The gear is supported by two tapered roller bearings, called **pinion bearings**.

By design, the axial centerline of the drive pinion gear lies below that of the ring gear. With this design, the pinion gear is placed lower in the rear axle housing. This is done to lower the drive shaft and, therefore, the drive shaft hump in the vehicle passenger compartment. The spiral design of the gear teeth allows the gears to mesh with a sliding motion, creating a smooth power transfer. As a result of the sliding action, the gears must have a good supply of the proper lubricant. Gears of this type are called hypoid gears.

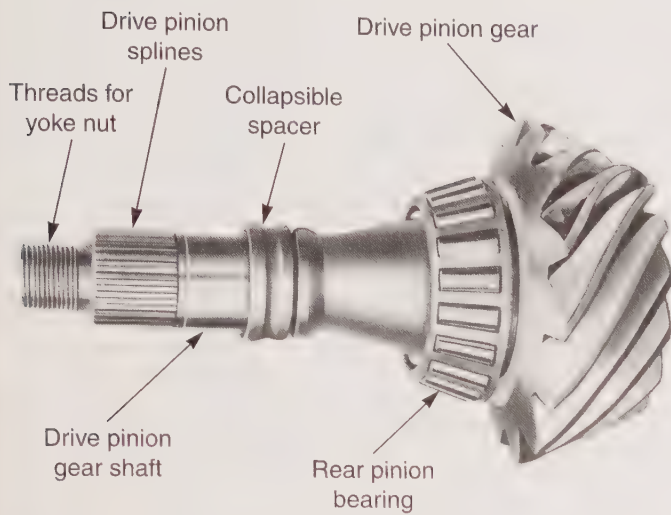


Figure 16-5. A typical drive pinion gear. The rear pinion bearing is pressed on the drive pinion gear shaft. A collapsible spacer is used to aid in pinion bearing installation. Threads and splines at the front of the drive pinion gear shaft are used for installing the differential pinion yoke. (General Motors)

The rear pinion bearing is pressed onto the drive pinion gear shaft at the gear end. The front pinion bearing is often a slip fit on the smaller end of the shaft. The outer races, or bearing cups, of both bearings are pressed into the rear axle housing.

Either a solid spacer or a collapsible spacer (crush washer) is used to set the pinion bearing preload. The **collapsible spacer** is designed to be slightly compressed when the drive pinion gear is installed in the rear axle housing. The spacer maintains a mild pressure between the front and rear pinion bearings, making it possible to accurately adjust the bearing preload.

The differential pinion yoke/flange has internal splines that fit the external splines on the drive pinion gear shaft. See **Figure 16-6**. The rear of the yoke/flange, where it fits into the rear axle housing, is machined smooth. This is the sealing surface for the pinion seal. The yoke/flange is held

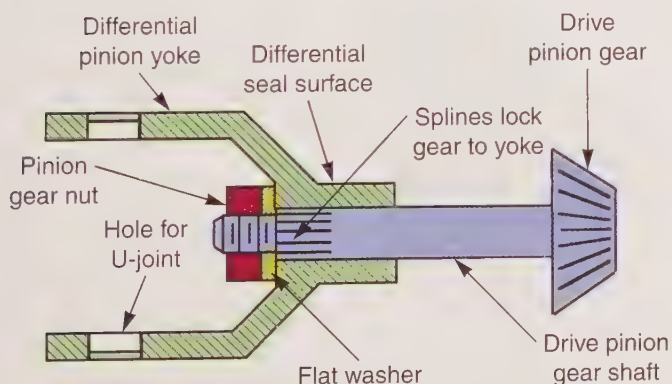


Figure 16-6. The differential pinion yoke slides over the drive pinion gear shaft and is secured by the pinion gear nut. The tightening nut also preloads the pinion bearings. The outer surface of the drive pinion gear shaft seals against the front oil seal.

to the drive pinion gear shaft by a large nut and washer that threads onto the shaft. This nut is a type known as a **jam nut**. The top threads of the nut are deformed to tightly grip the threads on the drive pinion gear shaft. This is an interference fit. Tightening the nut also adjusts the pinion bearing preload.

The pinion yoke is machined to accept the bearing cups of the rear universal joint. The cups are either pressed in and held with snap rings, or they are attached to the yoke with U-bolts or bolted-on straps.

Pinion flanges are simply a two-piece yoke joined by mating flanges. The outer section has the yoke; the inner section has the external splines for the pinion gear shaft. These companion flanges, as they are also called, would be separated at the flanged section to remove the drive shaft assembly, **Figure 16-7**.

The position of the drive pinion gear relative to the ring gear must be set exactly. Otherwise, the gears will be noisy and will wear out quickly. The position of the drive pinion gear in the housing must be carefully adjusted so that it contacts the ring gear at exactly the right tooth depth. To make this adjustment to the ring and drive pinion clearance, a **pinion shim** is installed in the housing, behind the rear bearing cup. The thickness of this shim determines the depth of the drive pinion gear in the housing. This shim is installed at the factory when the rear end is assembled. It must be checked for proper thickness whenever the drive pinion gear is removed.

Figure 16-8 shows the position of the pinion shim on most rear axle assemblies. This figure also shows the relative position of the collapsible spacer.

Ring gear

The **ring gear**, **Figure 16-9**, transfers power from the drive pinion gear to the differential case. Both the ring gear and the case are machined to fit together tightly. Bolts are

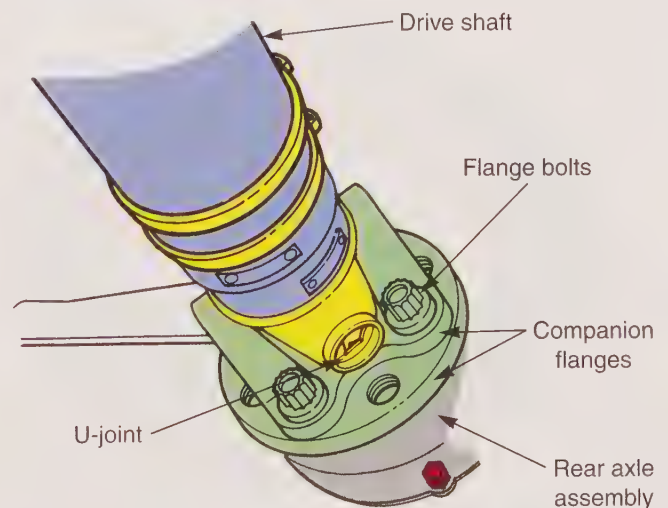


Figure 16-7. Some differential pinion yokes are two-piece flanged assemblies, as shown here. This type of design is referred to as a differential pinion flange, or companion flange. (Ford)

Differential Case Assembly

When a vehicle makes a turn, the outer wheel travels a greater distance than the inner wheel—the arc (or radius) of the turn is greater at the outer wheel. If the rear drive axles were simply connected together, both wheels would have to travel an arc of the same length during a turn. Since this is impossible, one of the tires would lose traction, or slip, during the turn. If the tire did not slip, it would skip over the road surface. This condition is called **wheel hop**.

The purpose of the differential case assembly is to allow the vehicle to make turns without slippage or wheel hop. It does this with an arrangement of gears that allows the rear wheels to turn at different speeds. Two basic types of differential case assemblies used to accomplish this task are the standard differential and the locking differential.

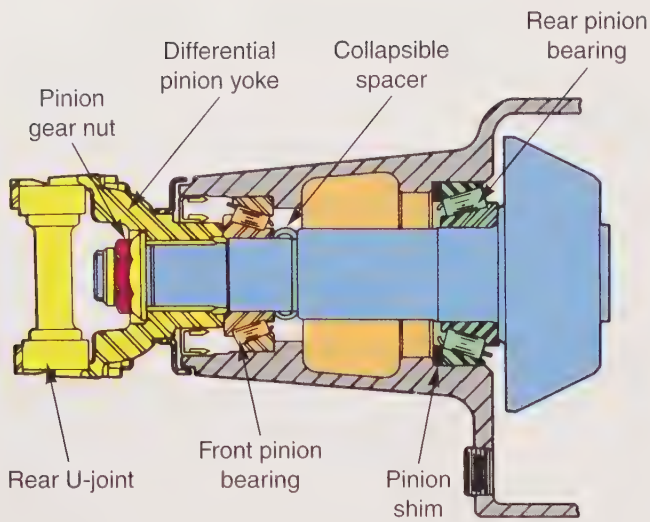


Figure 16-8. Pinion shim and preload spacer locations. Proper pinion adjustment is critical. The adjusting nut, preload spacer, and depth shim are all critical to proper pinion adjustment. (Chrysler)

used to hold the ring gear to the case. The bolts pass through holes in the case and are threaded into tapped holes in the back of the ring gear.

Since the ring and drive pinion gear teeth must mesh accurately to transmit motion without noise or damage, the position of the ring gear is important. Automotive technicians should be familiar with gear terminology that will be encountered while adjusting the differential assembly to obtain correct gear positions. The convex side, or drive side, and the concave side, or coast side, of the ring gear are pointed out in **Figure 16-9A**. These terms will be used when differential gears are adjusted. The tooth parts that must be carefully adjusted are identified in **Figure 16-9B**. The terms heel and toe will be used extensively for ring and pinion gearset adjustment.

Standard differential

The **standard differential**, also called a **single-pull differential**, is composed of meshing spider and side gears enclosed in a differential case. See **Figure 16-10**.

The standard **differential case** is usually a one-piece unit. The ring gear is bolted to the case. The case is usually made of cast iron. Occasionally, it is made of aluminum. Side bearings are usually pressed onto the case.

The **spider gears** are made of hardened steel and are held in place by a steel shaft called the pinion shaft. The pinion shaft passes through the differential case and the center of the spider gears. It is attached to the case with a bolt. Spider gears are also called **pinion gears**.

Spider gears mesh with **side gears**, which are also made of hardened steel. When the ring gear and differential case turn, the spider and side gears also turn. Power flow is through the case, into the spider gears, and on into the side gears. The side gears are splined to the drive axles.

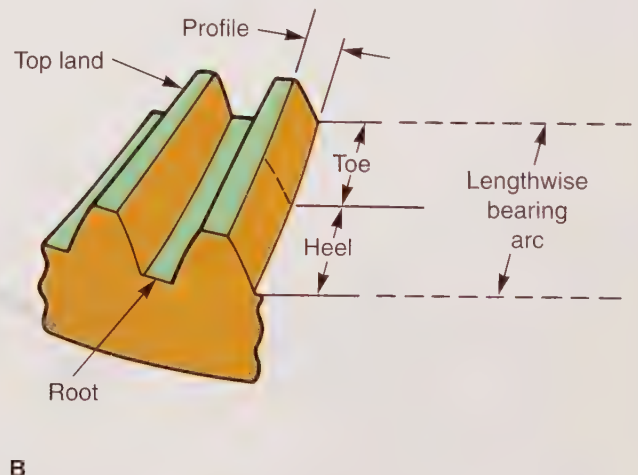
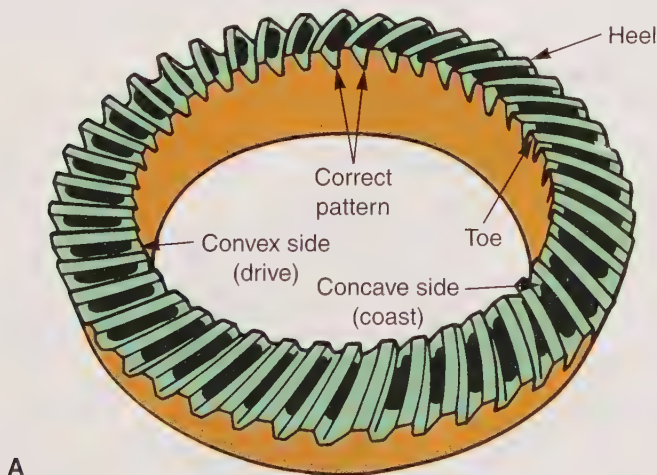


Figure 16-9. When installed, the ring gear is bolted to the differential case and meshes with the drive pinion gear. **A**—The ring gear has convex and concave sides. The convex side is the drive side. It contacts the drive pinion gear when the vehicle is accelerating. The concave side is the coast side. It contacts the drive pinion gear when the vehicle is decelerating. **B**—Gear terminology will be important when the differential assembly is serviced. Proper heel and toe contact is critical to quiet operation and long life. (General Motors, Chrysler)

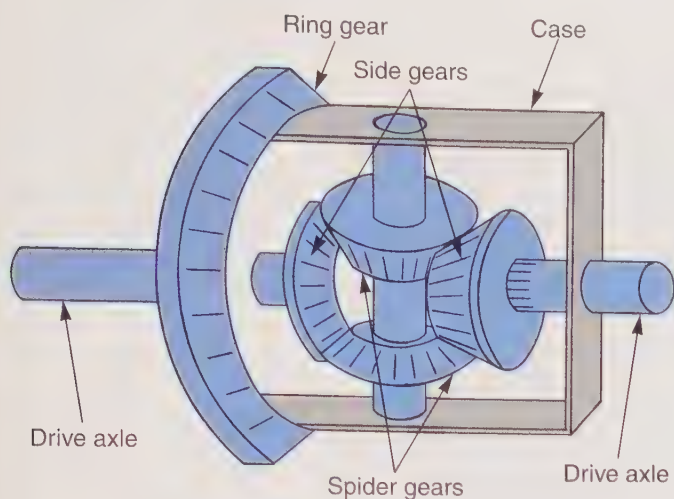


Figure 16-10. The basic components of a differential case assembly. The ring gear is bolted to the case, and the spider gears and side gears are mounted inside. On most differential assemblies, side bearings are pressed onto the case. All differentials contain the same general parts.

They transfer power to the drive axles and rear wheels. Side gears are also called **axle end gears**.

Some heavy-duty differentials contain four spider gears and two pinion shafts. In this design, there is a center hole in one of the shafts. The other shaft passes through it. The side gears are splined to the drive axle. On some differentials, the side gears contain C-locks, which hold the axles in place. See **Figure 16-11**.

The spider and side gears are bevel gears. Power transfer through the bevel gears causes them to be forced away from each other. This causes high thrust forces on the backs of the gears, where they contact the differential case. Hardened-steel washers are usually installed between the back of the gears and the case. These washers provide a sliding surface and reduce wear. See **Figure 16-12**.

Figure 16-13 shows the operating states of the differential while driving straight ahead and while driving around a corner. In **Figure 16-13A**, the vehicle is moving straight ahead and both wheels are traveling at the same speed. The spider and side gears rotate with the case but do not move in relation to it. The entire case assembly rotates as a unit.

When the vehicle makes a turn, the axles and the side gears begin turning at different speeds. The outer wheel—the left wheel, in the case of a right turn—turns faster than the inner wheel, and the left side gear turns faster than the right side gear. See **Figure 16-13B**. As a result of the different axle speeds, the spider gears begin to rotate. The left side gear, which is moving faster than the right side gear, drives the spider gears, causing them to rotate on, or walk around, the right side gear.

Note that the differential case speed on turns is the average of the side gear speeds. This is because one side gear is rotating faster than the case and the other side gear is rotating slower than the case. In **Figure 16-14**, when the vehicle makes a turn, the action of the differential allows

the outer wheel to turn at 110% of case speed, while the inner wheel turns at 90% of differential case speed. These percentages will vary with the radius of the turn.

Locking differential

The standard differential works well in most situations. However, on very slippery surfaces, such as icy or muddy roads, lack of traction can cause the rear wheels to slip. This is because the standard differential will drive the wheel with the least traction.

If one drive wheel is on dry pavement and the other is on ice or mud, the ring gear and differential case will drive the spider gears. However, the spider gears will not drive both side gears. When the spider gears are driven by the differential case, they will walk around the side gear related to the wheel on dry pavement. As a result, the spider gears drive the slipping wheel, and the vehicle will not move. The standard differential sends almost all engine power to the slipping wheel.

To overcome this problem, locking differentials are used. **Locking differentials** overcome traction problems by sending some power to both wheels, while allowing the vehicle to make normal turns. There are several different types of locking differentials, including limited-slip, ratchet, and Torsen® differentials.

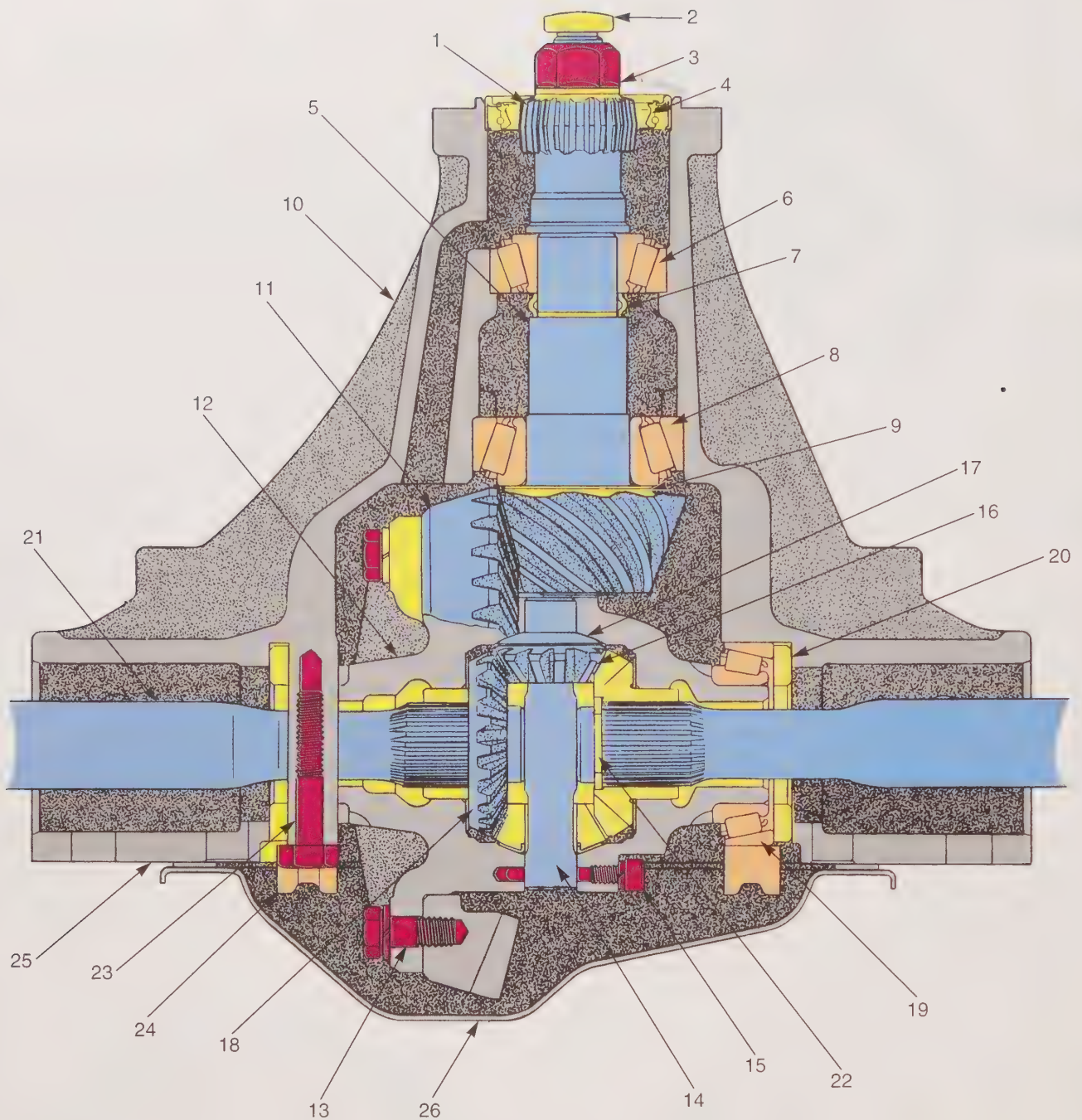
The two most common types of limited-slip differential are the clutch-plate differential and the cone differential. The clutch-plate differential uses several friction discs that look like small manual clutch discs. The cone differential uses a cone-shaped clutch that engages a matching cone-shaped receptacle. Limited-slip differentials have various brand names, including Positive Traction, Sure-Grip, Anti-Spin, Traction-Lok, and TXT. Many technicians refer to **limited-slip differentials** as Positraction differentials, although this is actually a General Motors brand name dating back to the 1950s.

Due to their complexity and higher cost, limited-slip differentials are used only on high performance versions of rear-wheel drive automobiles. Limited-slip differentials are commonly found on modern trucks and SUVs. Many SUVs and some trucks have limited-slip differentials on the front and rear axles. Some companies make aftermarket limited-slip differentials to replace original equipment designs or to convert standard differentials to limited slip units.

An example of a common **clutch-plate differential** is shown in **Figure 16-15**. The most obvious difference between this limited-slip differential and a standard differential is the clutch packs placed between the side gears and the differential case.

The clutch friction discs are made of steel covered with a friction material. The clutch plates are made of steel. The discs and plates are alternately splined to the side gear and dogged (meaning tabs fit into grooves) to the differential case, **Figure 16-16**. Grooves in the discs or plates are for better grabbing power.

Figure 16-17 shows the moving parts of a clutch-plate differential. The spider gears, side gears, and other parts are very similar to those used in a standard differential. The



- | | | | |
|-------------------------|--------------------------|-------------------|-------------------------------|
| 1. Drive coupling | 8. Rear pinion bearing | 15. Lock screw | 21. Drive axle |
| 2. Thrust washer | 9. Pinion depth shim | 16. Pinion gear | 22. Drive axle C-lock |
| 3. Lock nut | 10. Differential carrier | 17. Thrust washer | 23. Bearing cup bolt |
| 4. Oil seal | 11. Ring gear | 18. Side gear | 24. Bearing cup |
| 5. Drive pinion gear | 12. Differential case | 19. Side bearing | 25. Differential cover gasket |
| 6. Front pinion bearing | 13. Ring gear bolt | 20. Shim/spacer | 26. Inspection cover |
| 7. Preload spacer | 14. Pinion shaft | | |

Figure 16-11. A section view of a typical differential contained in rear axle assembly. The differential case is installed in the rear axle housing. The ring gear, which is attached to the differential case, meshes with the drive pinion gear. The relative positions of the parts are similar on all differentials. Note the C-locks on the differential side gears. They retain the drive axles in the housing. (General Motors)

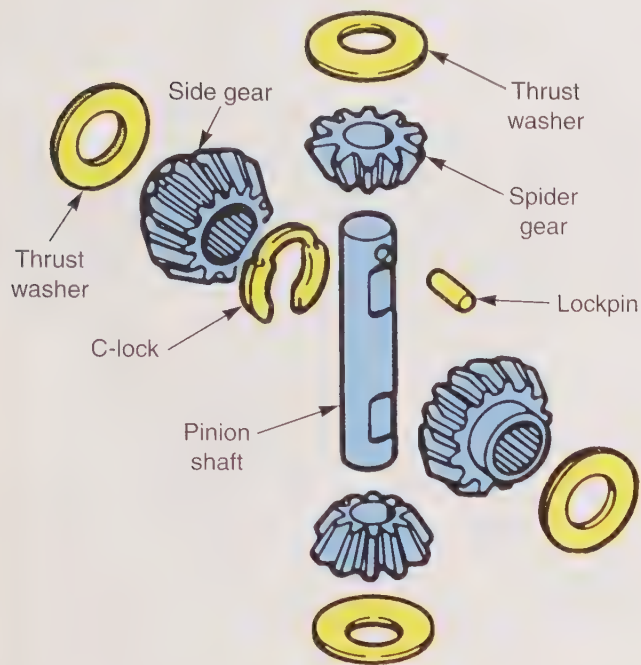


Figure 16-12. This is an exploded view of the differential gears. Note the relationship of the side and spider gears to each other. Also note the thrust washers that separate the gears from the case and the C-lock that holds the axle shaft in place. The pinion shaft is held in place by a pin that passes through both the shaft and differential case. (Chrysler)

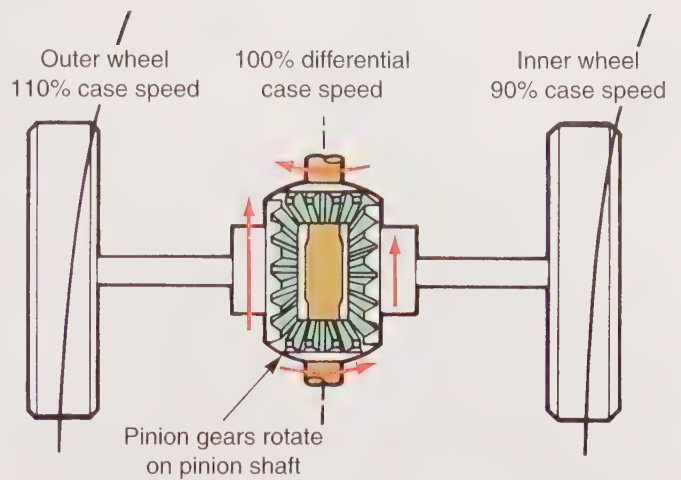


Figure 16-14. The speed of the differential case on turns is the average of the side gear speeds. (Chrysler)

differential case of the limited-slip differential is often made in two parts to allow for clutch pack removal, as shown in **Figure 16-18**.

The discs and plates are applied by the preload springs and by the mechanical pressure of the spider gears on the side gears. Since the spider and side gears are bevel gears, their teeth try to come out of engagement when the differential is transmitting engine torque. This creates a

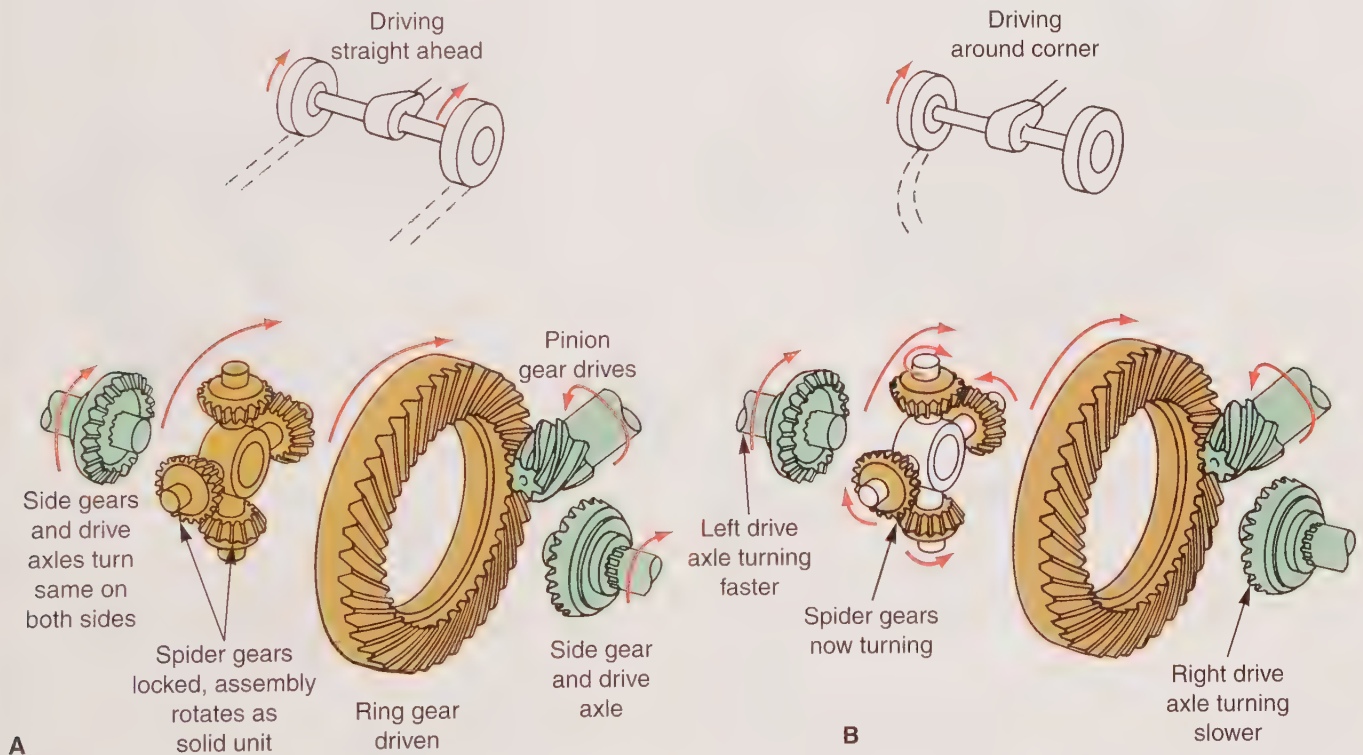


Figure 16-13. Differential action is shown here. Note the use of four spider gears, rather than the regular two. A—Straight ahead: Differential case gears turn as a unit. Both the drive axles and differential case are turning at the same speed. B—Right turn: The left axle is moving faster than the right axle. The left side gear drives the pinion gears. The pinion gears turn and walk around the right side gear. Note that the differential works the same way for a left turn, except the action of the left and right sides is reversed. (Deere & Co.)

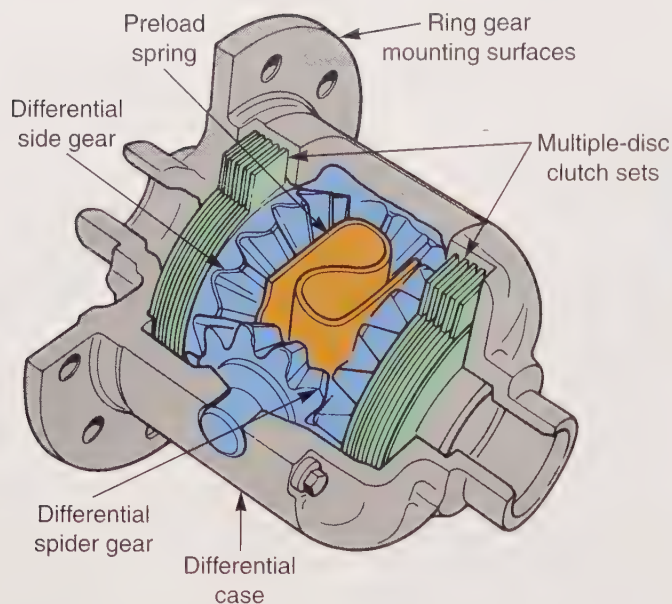


Figure 16-15. Study the assembled view of the clutch-plate differential. The clutch packs are sandwiched between the side gears and differential case. The preload spring applies initial force to the clutch packs but still allows enough slippage in the clutch pack for normal differential operation. (Ford)

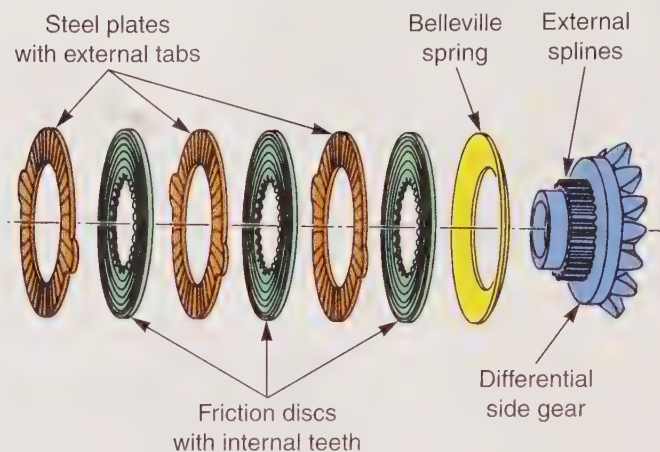


Figure 16-16. Exploded view shows the clutch pack of a limited-slip differential. Each clutch pack has the same number of clutch discs and plates. Note the internal teeth on the friction discs and the external tabs on the steel plates. Grooves in the discs and plates reduce the chance of slippage. (Chrysler)

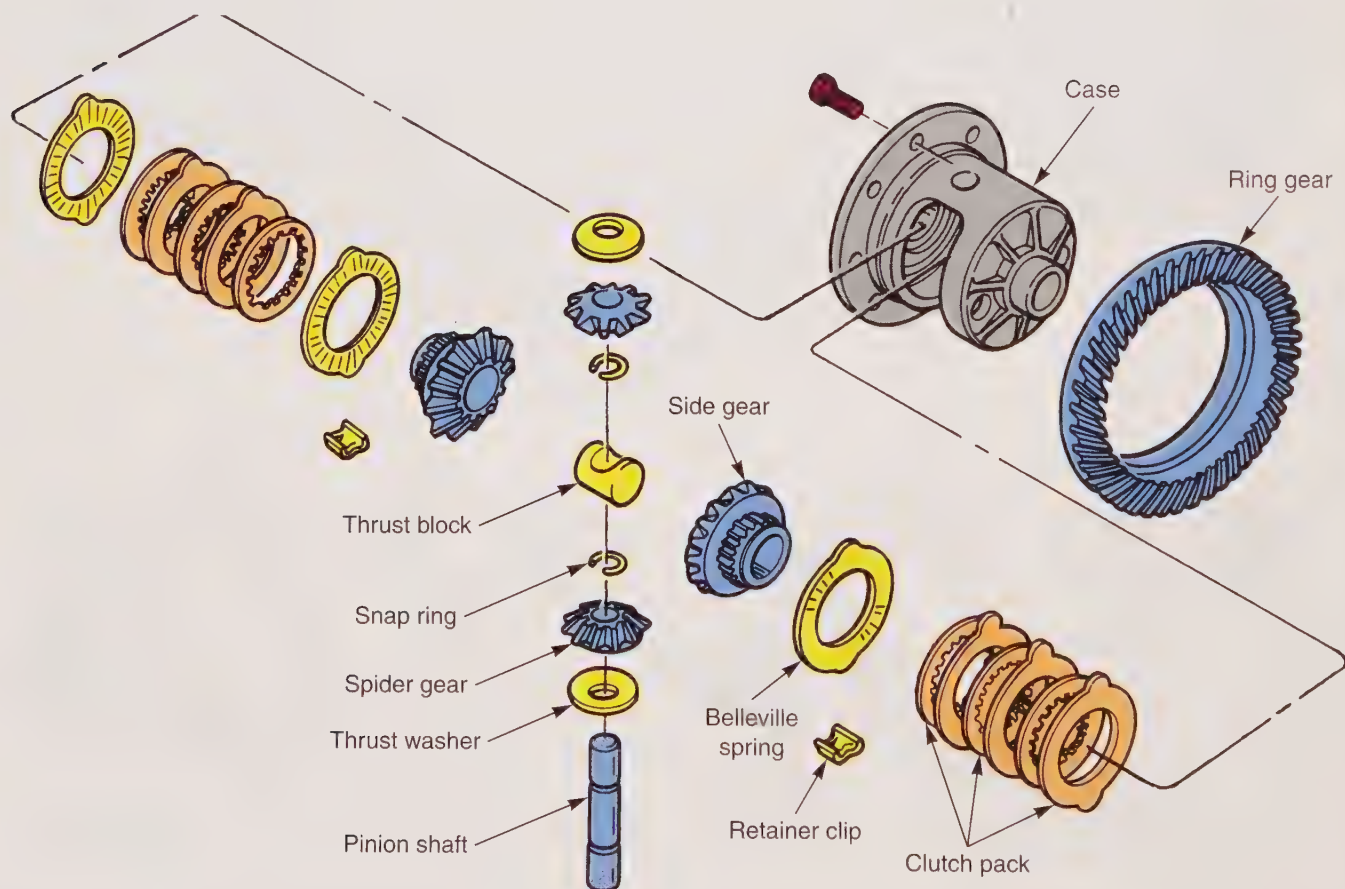


Figure 16-17. This shows the relative positions of the clutch packs, spider gears, and side gears of the limited-slip differential. Notice the similarity to the standard differential. (Chrysler)

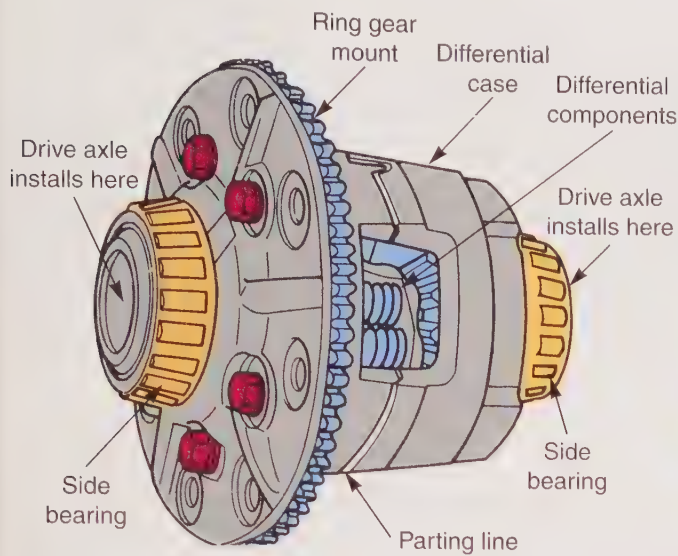


Figure 16-18. The differential case of a limited-slip differential is often made in two parts. Note the parting line on the case of this limited-slip differential. (Chrysler)

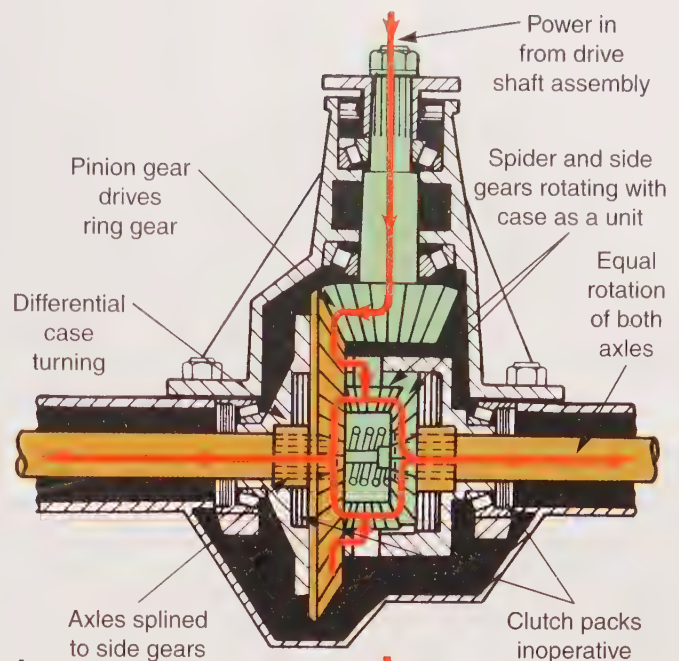
pushing action on the side gears, forcing them outward against the differential case. The outward pressure of the side gears presses the friction discs and steel plates together between the side gears and the case. Whenever the discs and plates are pressed together, the splined and dogged connections ensure the side gear and differential case are locked together.

The operation of a clutch-plate differential is shown in **Figure 16-19**. When the vehicle is moving straight ahead, the clutch-plate differential operates in the same manner as a standard differential, **Figure 16-19A**. The rear wheels and the differential case turn at the same speed. The clutch packs are applied, but they are not needed.

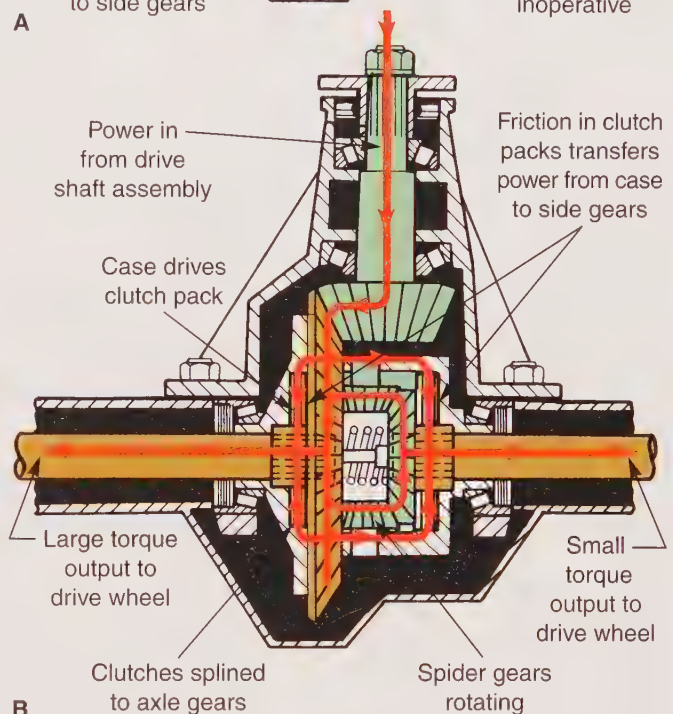
When turning, the vehicle loses traction at one wheel, causing the wheel to slip, **Figure 16-19B**. Since the wheel is slipping, the spider gears do not press tightly on the side gear of the slipping wheel. The side gear also does not press toward the case, and the clutch pack of the slipping wheel is not pressed tightly together.

Since there is a tendency for the side gears to move away from the spider gears under load, the other side gear moves outward and away from the spider gears. The side gear is under load because its related wheel has traction. The pressure on this side gear causes the related clutch pack to be pressed tightly together. The side gear is locked to the case by the clutch pack, and power is delivered to the wheel with traction.

The clutch pack is designed to slip when some preset torque value is reached. When the vehicle is making a turn, a high torque, caused by the outer wheel rotating faster than the case, causes the clutch pack to slip. This allows the differential to operate in the same manner as a standard differential when making turns. The discs and plates slide against each other—discs turning with side gears, plates turning with case—allowing different rotating speeds between case and side gears and, therefore, between rear wheels.



A



B

Figure 16-19. Study the action of the limited-slip differential. **A**—Traction on both wheels. The differential parts are locked together and rotate as a unit. The clutch packs are not operating. **B**—One wheel is slipping. Pressure on the side gear of the wheel with traction causes the discs and plates of the related clutch pack to grab, sending most of the engine power to that wheel.

Figure 16-20 shows a **cone differential**, which is another version of the limited-slip differential. In place of clutch packs, friction-lined cones are used. The operation is similar to that of the clutch-plate differential. Preload spring and side gear pressures force the cone into a dished depression in the differential case. Friction tries to lock the cone and, therefore, the side gear to the case, sending

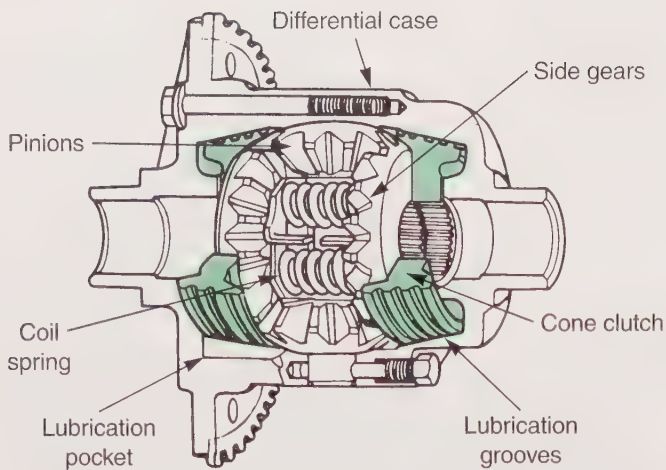


Figure 16-20. Study the construction of the cone differential. The operation of this limited-slip differential is similar to that of the clutch-plate differential. Pressure on the side gear of the wheel with traction causes the cone to be pressed into the dished area of the differential case, locking the case to the drive axle on that side. (Chrysler)

power to the wheel with the most traction. **Figure 16-21** is an exploded view of the cone differential.

Note that both clutch-plate and cone differentials require special limited-slip gear oil. Using ordinary gear oil in limited-slip differentials will cause the discs and plates or cones to slip and vibrate during turns.

The **ratchet differential**, nicknamed a Detroit locker, uses a series of cams and ramps to direct power to the wheel with the most traction. Its operation depends on relative wheel speed, rather than on wheel traction. The ratchet differential transfers power through a set of teeth that can be engaged and disengaged. This kind of engaging teeth system is sometimes called a dog clutch. The series of cams and ramps disengage the teeth of the dog clutch on

the side of the wheel with the least traction. An example of the ratchet differential is shown in **Figure 16-22**.

For straight-ahead driving, both sets of teeth are engaged, and the differential case and wheels turn at the same speed, **Figure 16-22A**. During turns or when one wheel loses traction, the speed difference between the wheels causes the internal cam and ramp to disengage the teeth on the side of the faster moving wheel, **Figures 16-22B** and **16-22C**. All power is then sent through the other wheel.

Since the faster moving wheel is always the one that is slipping, power always goes to the wheel with traction. On turns, the loss of power to the outer wheel is not noticeable. This design is durable and does not require special gear oil, but it is often rough and noisy in operation. It is usually used in off-road and racing vehicles.

The **Torsen differential** is a locking differential using complex worm gearsets. The gearsets include worms (drive gears) and worm wheels (driven gears). The Torsen differential has been available since the 1960s as a high-performance replacement unit for standard differentials. It is now being offered as original equipment on some European cars. The basic mechanical principle of this differential is that while the worm can drive the worm wheel, the worm wheel cannot drive the worm.

As shown in **Figure 16-23**, the Torsen differential has two central worms. For purposes of clarity, these will be referred to as axle gears. One axle gear is attached to each axle shaft. Worm wheels ride on and are driven by the axle gears. The worm wheels are held in place by the differential case. Spur gears machined on the ends of the worm wheels mesh and form the only connection between the two axle shafts. Engine power drives the differential case, and the worm wheels, held by the case, turn with it. The worm wheels cannot turn the axle gears, so they lock themselves to the gears. In this way, power is transmitted; the axle gears and axles are locked to the case, and they rotate with it.

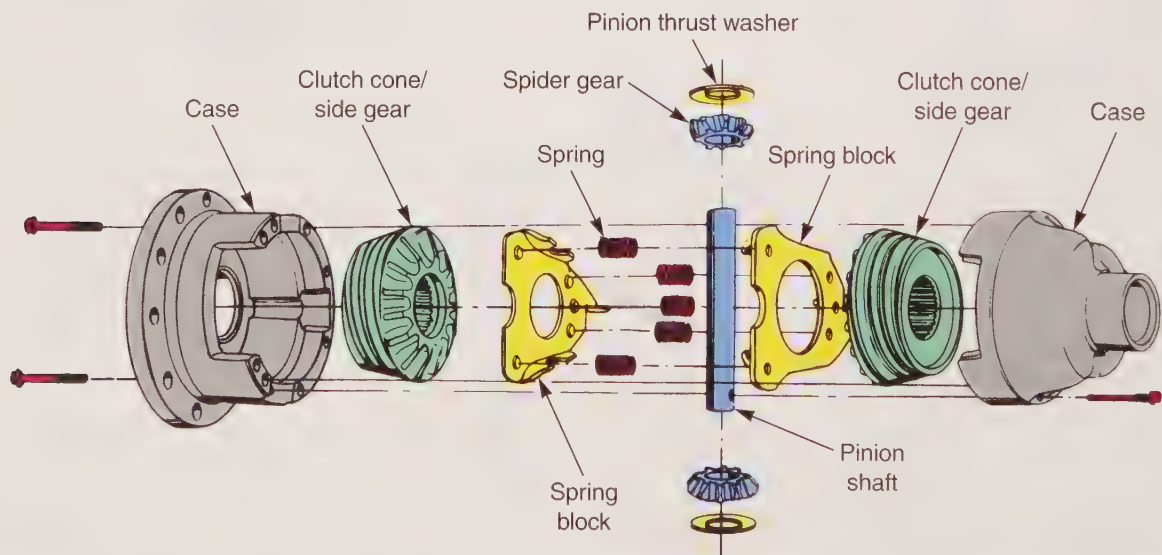


Figure 16-21. Exploded view of the cone differential shows the relationship of parts. Grooves in the cones help to solidly engage the case. (Chrysler)

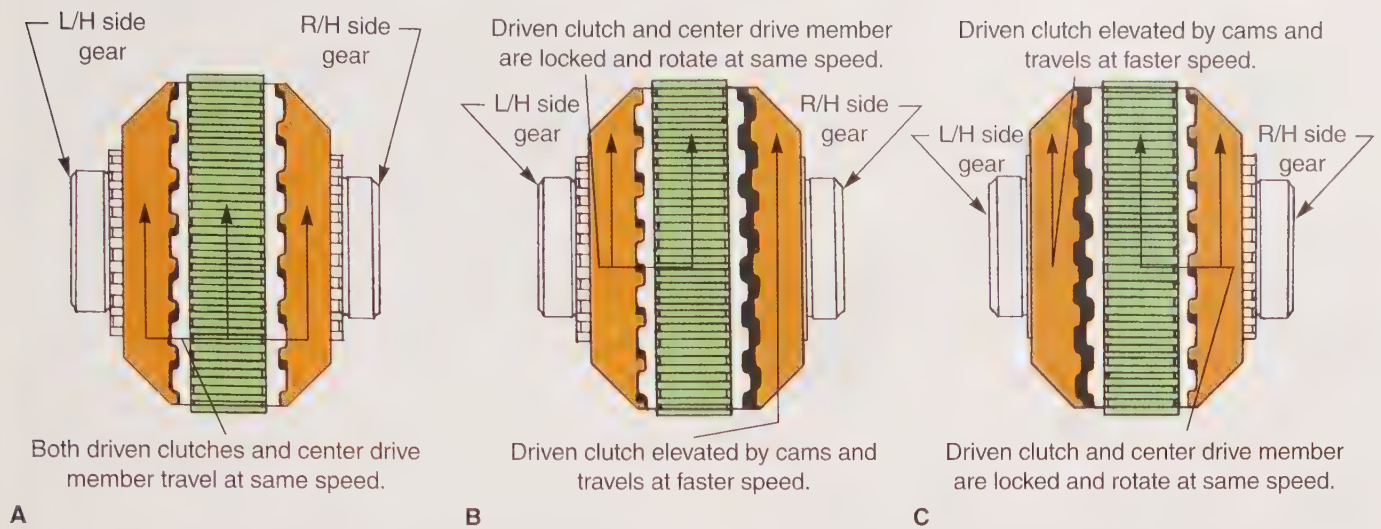


Figure 16-22. The ratchet differential uses matching sets of teeth on each side of the differential case. Teeth are engaged and disengaged to transfer power. A—Differential is straight-ahead operation. Teeth are engaged on both sides of the case, and power is transferred equally to each wheel. B—When the vehicle makes a left turn, the greater speed of the right wheel causes the internal cam on the right side of the case to take the right-side teeth out of engagement. All power goes through the left axle and wheel. C—When the vehicle makes a right turn, the greater speed of the left wheel causes the left-side cam to take the left-side teeth out of engagement. All power goes through the right axle and wheel. (Ford)

During straight-ahead operation, the differential assembly operates like a standard differential; all internal gears turn as a unit. When the vehicle is making a turn, or when one drive wheel is slipping, the relative speed of the drive wheels and, therefore, of the axles, changes. This

speed change is transmitted from the faster axle to the slower one by the action of the meshing spur gears.

The axle gear on the faster axle can drive the respective worm wheels. This driving force is transferred from the spur gears on the faster turning worm wheels to the spur gears on the slower turning worm wheels. Engine power is transferred from the faster to the slower worm wheels by the interaction of the gears. The worm wheel on the slower side still cannot drive the slower axle gear, but it can transfer the increased power from the faster wheel as pressure. This pressure increases the amount of power sent to the slower axle gear and axle. It does not turn the axle gear, but it does allow it to turn with more force.

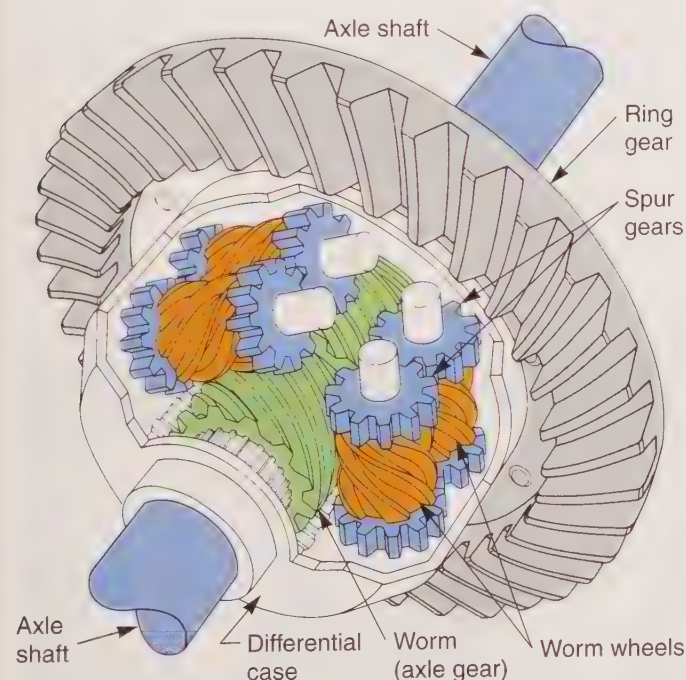


Figure 16-23. The Torsen differential uses a unique arrangement of gears to transfer power. This differential has been available as a high-performance aftermarket replacement for about 25 years. It is now being offered as original equipment on some European vehicles. The operation of this differential is complex. (Torsen)

Hydraulic Locking Differentials

Some late model SUVs have locking differentials that are operated by hydraulic pressure. It may be called a Hydra-Lock, Vari-lock, or Georotor system. A **hydraulic locking differential** consists of a pump with internal and external gears, a ring-shaped pressure diaphragm, and a clutch pack that resembles the clutch pack used in a conventional locking differential, **Figure 16-24A**. The gear oil that operates the hydraulic system comes from the rear axle assembly sump. Special oil is not needed. The same oil is used for rear axle lubrication, and the hydraulic system does not have to be sealed from the other rear axle components.

The pump resembles a rotor-type engine oil pump, with a six-point external gear that turns inside of an internal gear with seven cavities. The spaces between the pump internal and external gears are filled with gear oil at all times. When the gears move in relation to each other, spaces on the intake side of the pump open and draw in gear oil. The fluid is carried around to the output side of the pump, where the spaces begin to close. Closing the spaces

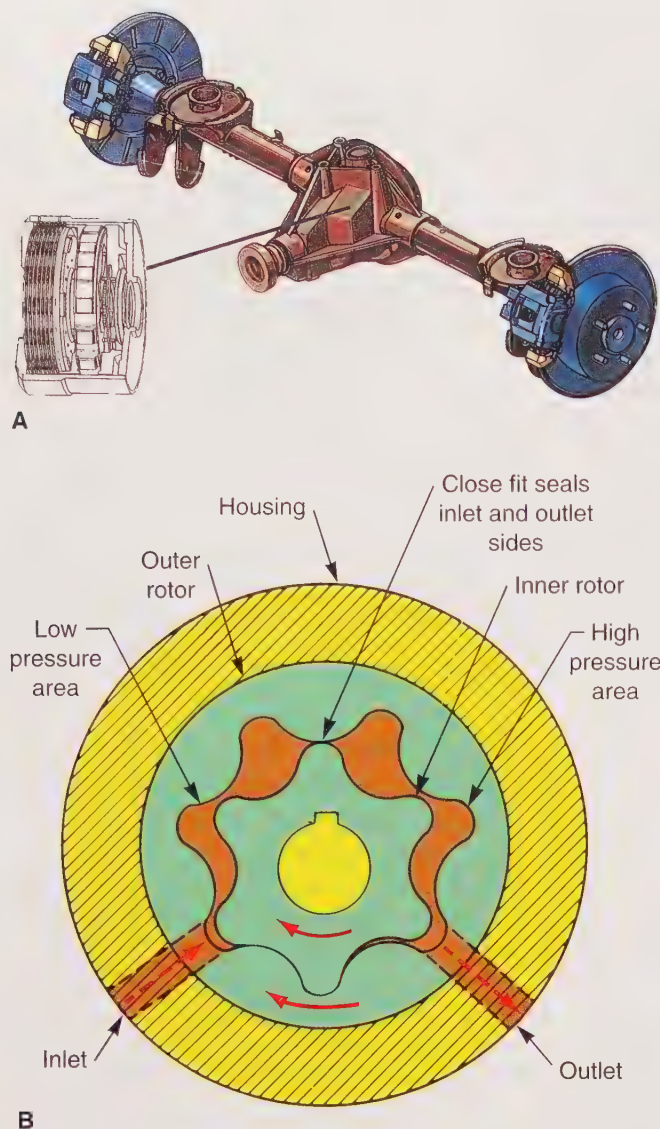


Figure 16-24. A—A hydraulic locking differential, consisting of a pump with internal and external gears, a ring-shaped pressure diaphragm, and a clutch pack. B—The arrangement of the internal and external rotor resembles a rotor type engine oil pump. The close fit of the inner and outer rotors forms a seal at the point where the teeth almost touch in the pumping chamber. (Chrysler)

produces pressure that can be used to operate the other components of the differential assembly. **Figure 16-24B** shows the operation of a rotor-type pump. Check valves ensure that pressure is always produced, no matter what the direction of pump rotation.

The internal gear is attached to one of the side axles. The external gear is attached to the other side axle. When both wheels have equal traction, both side axles turn at the same speed. Therefore, the internal and external pump gears do not move in relation to each other, and no pressure is developed. When the vehicle loses traction to one wheel, one of the side axles begins turning at a faster rate than the other. The difference in axle speeds causes the internal and external pump gears to move in relation to

each other, producing hydraulic pressure. This pressure is delivered to the ring diaphragm, which expands against the clutch pack. With the clutch pack applied, the side axles lock together and turn as a unit. When the wheels begin turning at the same speeds, the internal and external gears do not move in relation to each other, and no pressure is produced. With no pump pressure produced, the ring diaphragm depressurizes and releases the clutches. If one wheel again begins to slip, the pump starts operating again, and the system reapplies the clutches.

When the vehicle makes a turn, the pump gears move slightly in relation to each other. They do not, however, produce enough pressure to apply the clutches. Therefore, the differential does not attempt to lock up during normal turns.

Some locking differentials are operated by an electric motor attached to the axle assembly. Note the additional parts installed on a standard rear axle, **Figure 16-25**. The shift fork shaft and shift fork are operated by the motor and move a hub sleeve. The hub sleeve has splines that can engage matching splines on the differential carrier and side gear. During normal non-locking operation, the shift fork shaft and shift fork are positioned to keep the hub sleeve disengaged. The hub sleeve has no effect on differential operation.

To lock the differential, the motor moves the shift fork shaft and shift fork to engage the hub sleeve splines with the splines on the differential carrier and side gear. The splines lock the hub sleeve, differential carrier, and side gear into a single unit. Locking the carrier and side gear together prevents the other differential gears from turning. The differential assembly turns as a unit, delivering equal power to each drive wheel.

Rear Axle Housing: Solid-Axle Rear Suspension

The rear axle housing contains and supports other parts of the rear axle assembly. It also forms a reservoir for the rear end lubricant. The housing accommodates suspension system attachment. Most rear axle housings also support the stationary parts of the rear brake assemblies.

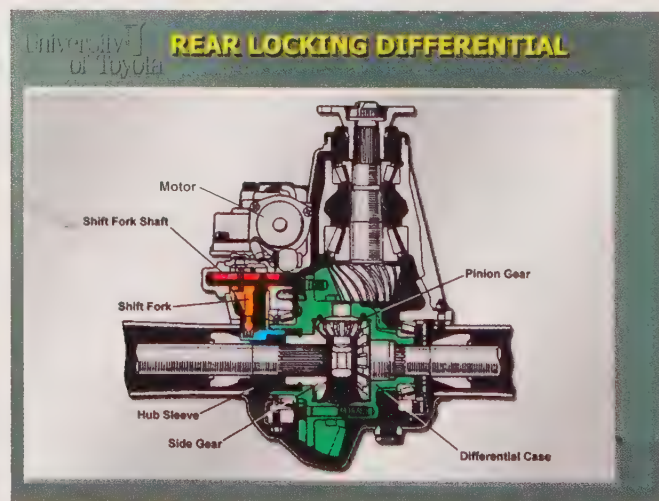


Figure 16-25. Rear locking differential. (Toyota)

The rear axle housing associated with solid-axle rear suspension consists of a central housing, or **differential carrier**, and **axle tubes**, which enclose the drive axles and extend to the rear wheels. (Vehicles with independent rear suspension will not have axle tubes.) Rear axle housings will have a vent to relieve pressure buildup. They will also have oil drain and fill plugs. See **Figure 16-26**.

Most rear axle housings are made of steel. Steel axle tubes are pressed and welded into the housing or are cast integral with the housing. The axle tubes usually have an integral flange at the outer end. The flange provides a mounting surface for the brake backing plate and an axle retainer plate.

Since the rear axle housing is a solid structure, it moves up and down with the wheels as they move over bumps and holes. To control this movement, the rear axle housing is attached to the vehicle body through an arrangement of springs, shock absorbers, and control arms, **Figure 16-27**. These parts align the rear axle assembly to the vehicle while isolating most of the axle movement.

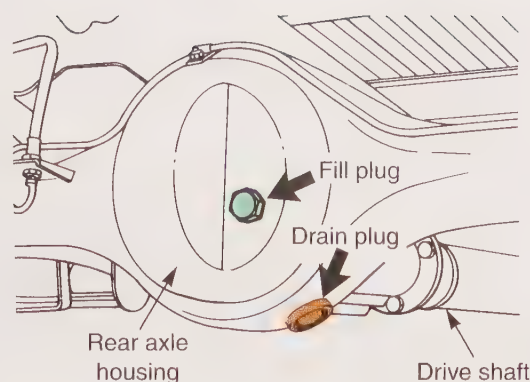
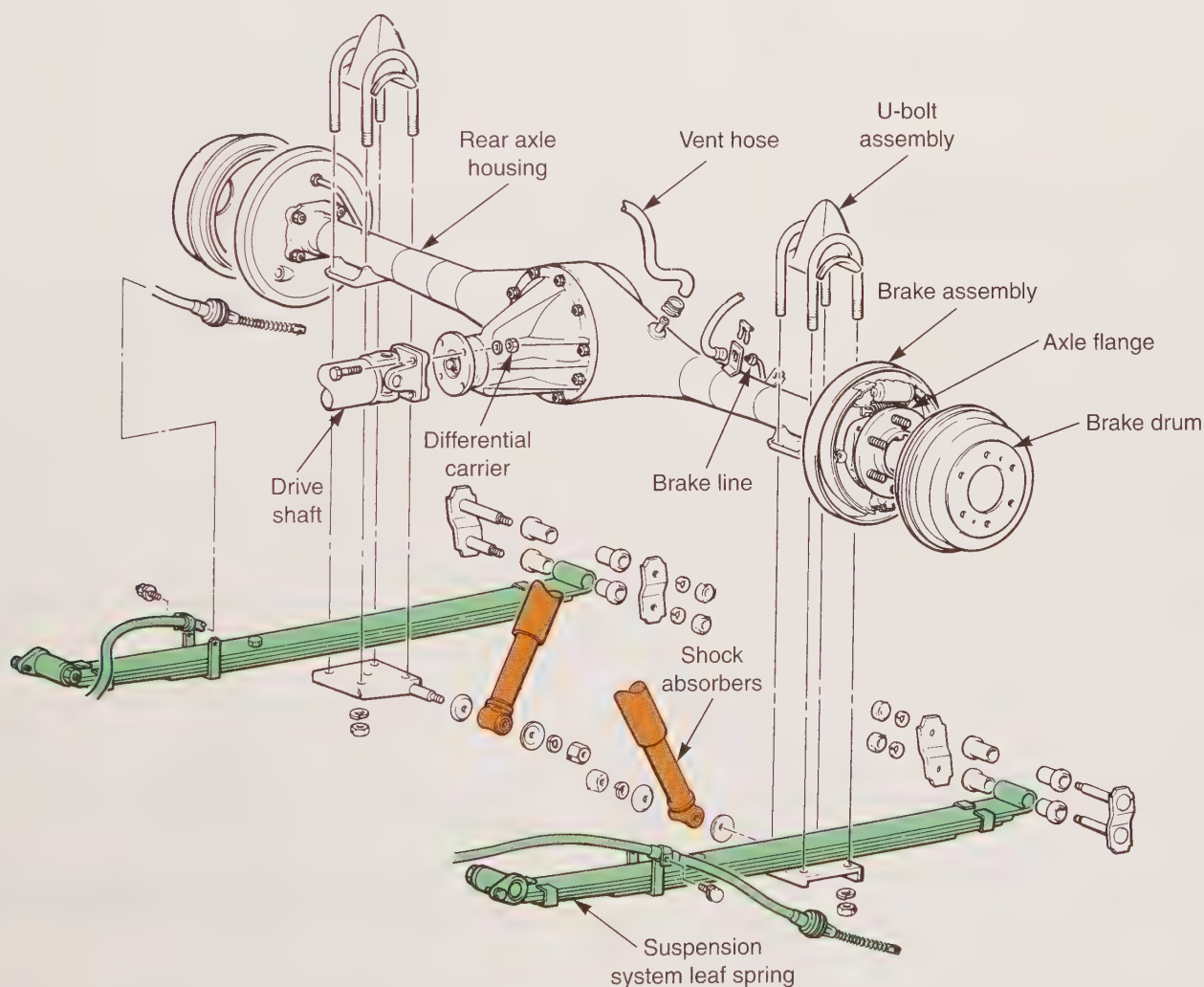


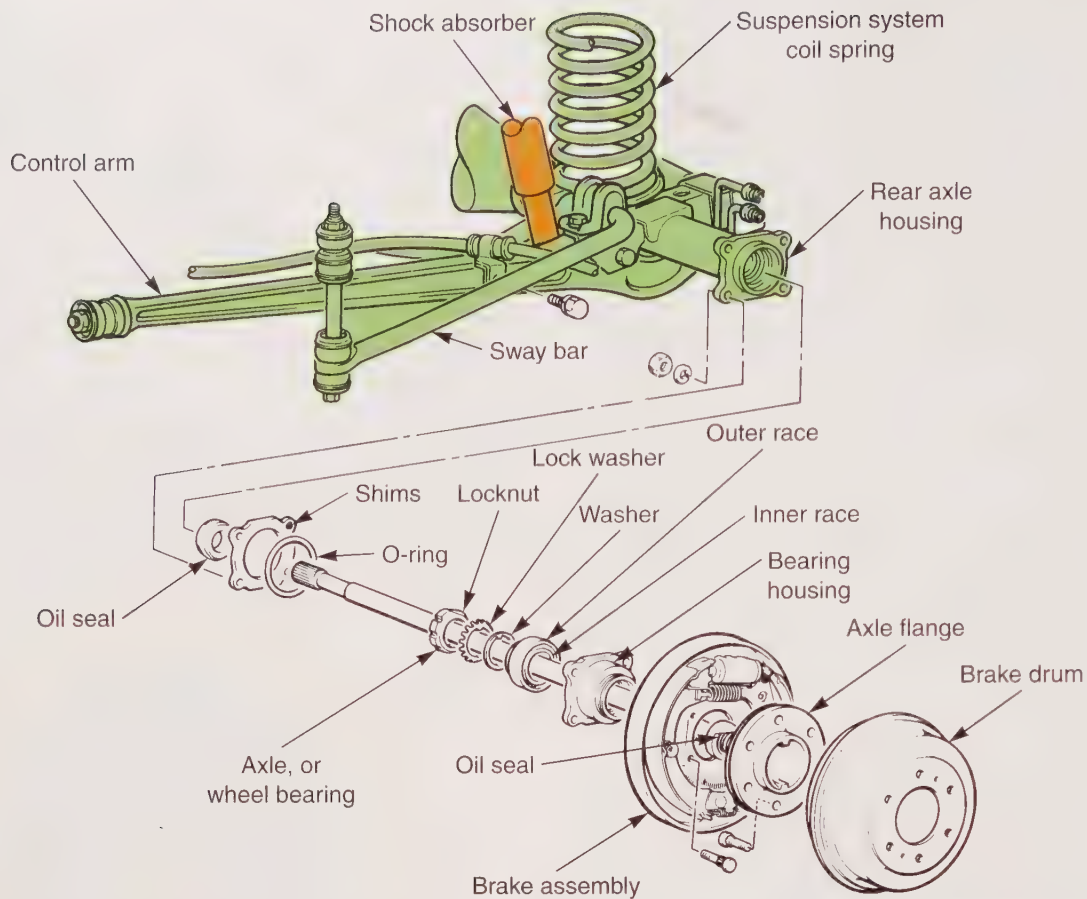
Figure 16-26. Rear axle assemblies will almost always have fill plugs but not necessarily drain plugs. On a differential without a drain plug, the inspection cover or carrier must usually be removed to drain the oil. Oil can sometimes be drained by removing the lowest inspection cover-attaching bolt. (Chrysler)



A

Figure 16-27. Two methods of suspending the rear axle assembly of a vehicle with a solid-axle rear suspension are shown. Both methods involve the use of conventional shock absorbers. A—Leaf springs support and align the rear axle assembly. This method simplifies the assembly, but makes the removal of the rear end difficult.

(continued)



B

Figure 16-27. (continued). B—Coil springs require the use of control arms and sway bars to maintain alignment. This method makes for easier rear end removal. (Chrysler)

Leaf springs support the axle and hold it in alignment, eliminating the need for control arms, **Figure 16-27A**. When coil springs are used, separate control arms must be used to maintain rear axle alignment. See **Figure 16-27B**.

Two kinds of rear axle housings are used on vehicles without independent rear suspensions—removable carrier and integral carrier. Both types will be discussed in this section. (Rear axle housings used with independent rear suspension will be discussed in the section that follows.)

Removable Carrier

The **removable carrier** has a separate housing for the differential assembly, **Figure 16-28**. It can be unbolted and removed from the rest of the rear axle housing after the drive axles are removed. All of the internal differential parts, then, will be removed with it. Differential assemblies housed in this kind of carrier are, in general, easier to service, since repairs can be done on the bench instead of on the vehicle.

The carrier mounting flange is where the carrier attaches to the rest of the rear axle housing. Usually, threaded studs are installed in the housing. The studs pass through holes in the mounting flange when the carrier is installed. The carrier is then tightened in place by installing

and tightening nuts over the threaded studs. This attaching method makes it easier to align and reinstall the carrier. A gasket is always used between the carrier and axle housing.

The differential pinion bearings are installed in the carrier in the pinion bearing bores. When tapered roller bearings are used, the bearing cups are tightly pressed into the bores. Some removable carriers have an extra support bearing at the end of the pinion gear. This bearing is called a **pinion pilot bearing**.

Figure 16-29 shows the attaching points for the differential **side bearings**, also called **case bearings**. The side bearings are held in place by bolted, U-shaped caps. Most

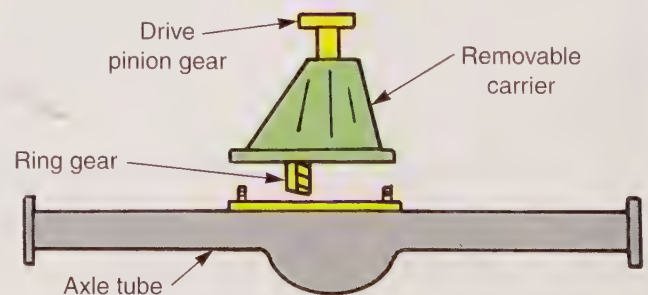


Figure 16-28. The removable carrier type of rear axle housing is a two-piece assembly. The carrier contains differential parts. It can be unbolted and, after the drive axles are removed, serviced on a bench.

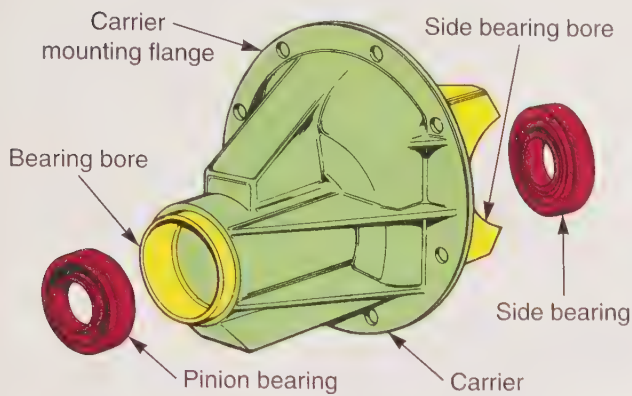


Figure 16-29. The mounting flange of a removable carrier is designed to seat against the axle portion of the rear axle housing. The carrier is attached with studs and nuts. The gasket is always installed between the carrier and the axle housing. (Subaru)

differential side bearing mounts have a provision for adjusting the side bearing preload. This adjustment is usually made with a threaded end cap, or adjusting nut. The end cap is tightened against the bearing cup until the proper preload is attained.

Drain and fill plugs may be mounted on the differential carrier or on the rear axle housing, depending on the particular manufacturer. The ribs on the front of the carrier strengthen it without adding a great deal of weight to the assembly.

Integral Carrier

The **integral carrier**, as the name implies, is an integral part of the rear axle housing. See **Figure 16-30**. This type of rear axle housing has a sheet metal or cast metal inspection cover, sometimes called the differential cover. The inspection cover can be removed to service the rear end components. Service operations must be performed under the vehicle, since the carrier cannot be separated from the rest of the rear axle housing.

Figure 16-31 shows a typical integral carrier. Notice that almost all the rear end components are installed inside

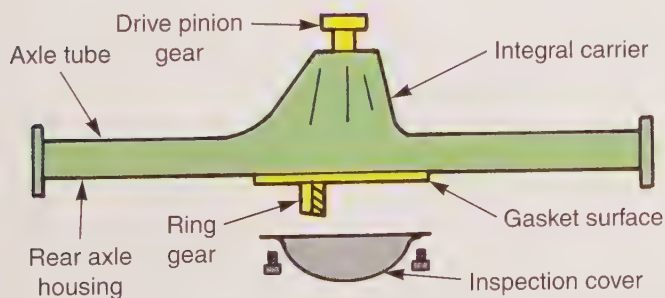


Figure 16-30. The rear axle housing with an integral carrier is essentially a one-piece unit. All moving parts are inside the housing. The differential parts are reached for service by removing the inspection cover at the rear. This type of axle is usually serviced under the vehicle.

the rear axle housing. Most of these can be removed through the opening that is kept closed off by the inspection cover. The cover is sealed with a gasket of some sort.

The pinion front and rear bearing cups are pressed into the carrier portion of the rear axle housing. Integral carriers do not normally have a pinion pilot bearing.

Differential side bearings are installed in the integral carrier in the same manner as on a removable carrier. The side bearing preload adjustment is sometimes made with shims. These shims are placed between the bearing cup and the rear axle housing. In other instances, the preload adjustment is made with a threaded end cap, as on the removable carrier.

Rear Axle Housing: Independent Rear Suspension

On vehicles having independent rear suspensions, a modified rear axle housing is used. **Figure 16-32** shows such a housing. Notice that the housing has no axle tubes. The drive axles resemble drive shaft assemblies to some degree, complete with conventional or constant-velocity universal joints. This design allows each wheel to react independently to the road surface, improving ride quality and handling.

The housing has oil seals to prevent oil loss where the axles enter the housing. The internal construction of the housing is identical to the previously discussed carriers. To reduce vibration and strengthen the drive train, a torque tube is sometimes used to attach the front of the housing to one of the vehicle crossmembers. (Torque tubes were explained in Chapter 12.)

Rear Drive Axles

The rear drive axles transfer power from the differential assembly to the rear wheels. There are two major kinds of drive axle designs. One is the solid drive axle, shown in **Figure 16-33**; the other is the independently suspended drive axle, shown in **Figure 16-34**.

Solid Drive Axle

A **solid drive axle**, or **live axle**, is a hardened-steel shaft. See **Figure 16-35**. Each rear axle assembly in solid-axle rear suspension systems has two. External splines on the inboard (inner) end of each axle mate with internal splines on the differential side gear to which it is connected. An **axle flange** at the outboard (outer) end of each axle acts as a wheel hub. It provides the mounting surface for the brake drum or rotor and the wheel. The brake assembly and wheel are installed directly on the flange wheel studs.

Each shaft is supported on the outboard end by an **axle bearing**, also called a **wheel bearing**. The axle

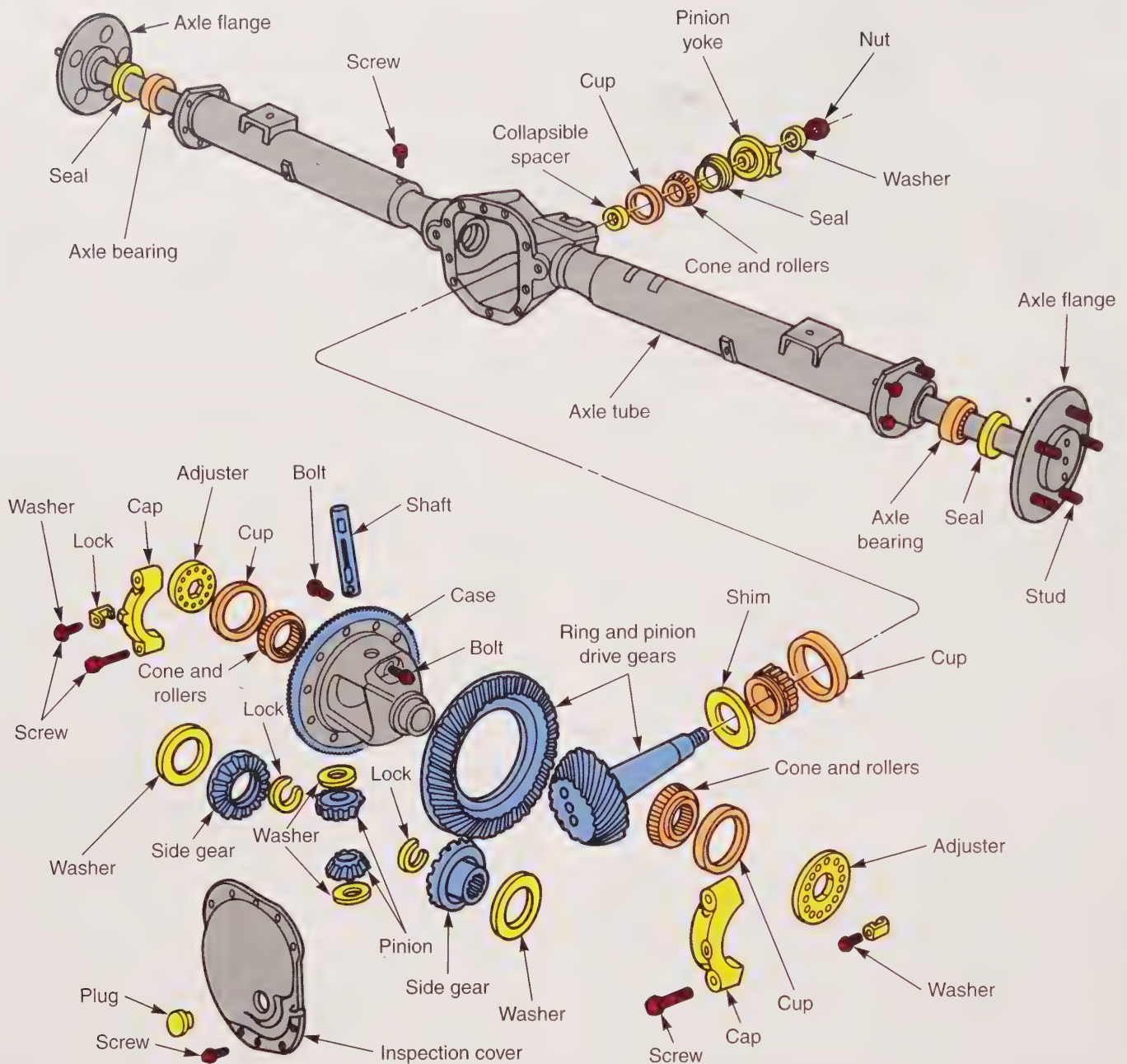


Figure 16-31. This is an exploded view of an integral carrier rear axle assembly. Notice that most of the moving parts fit inside the rear axle housing. The inspection cover often contains a fill plug. (Chrysler)

bearing can be installed on the shaft or in the axle tube.

Axle bearings that are installed on the shaft are usually packed with grease. An axle seal is pressed into the housing behind, or on the inboard side of, the bearing. The lip of the seal seats against a machined area of the shaft. This seal keeps rear end lubricant from reaching the bearing. An outer seal prevents water and dirt from leaking through the outer ends of the rear axle housing and entering the bearing.

Axle bearings that are installed in the housing are lubricated by rear end lubricant (gear oil). When the vehicle makes a turn, lubricant is thrown outward from the carrier, reaching the axle bearing. An axle seal is installed in front of, or on the outboard side of, the bearing to keep

lubricant from leaking out from the outer ends of the rear axle housing. The shaft is held in place by a clip as explained in the next section.

An axle bearing installed on the shaft is held in place by an **axle collar**. The axle collar is tightly pressed on the shaft. In addition, some will have a spacer to keep the bearing at the proper distance from the end of the axle. The **axle retainer plate** holds the axle and axle bearing to the axle tube.

Semi-floating axles

Solid drive axles can be semi-floating or full-floating. Most automobiles and light trucks have semi-floating axles. In the **semi-floating axle**, the weight of the vehicle passes

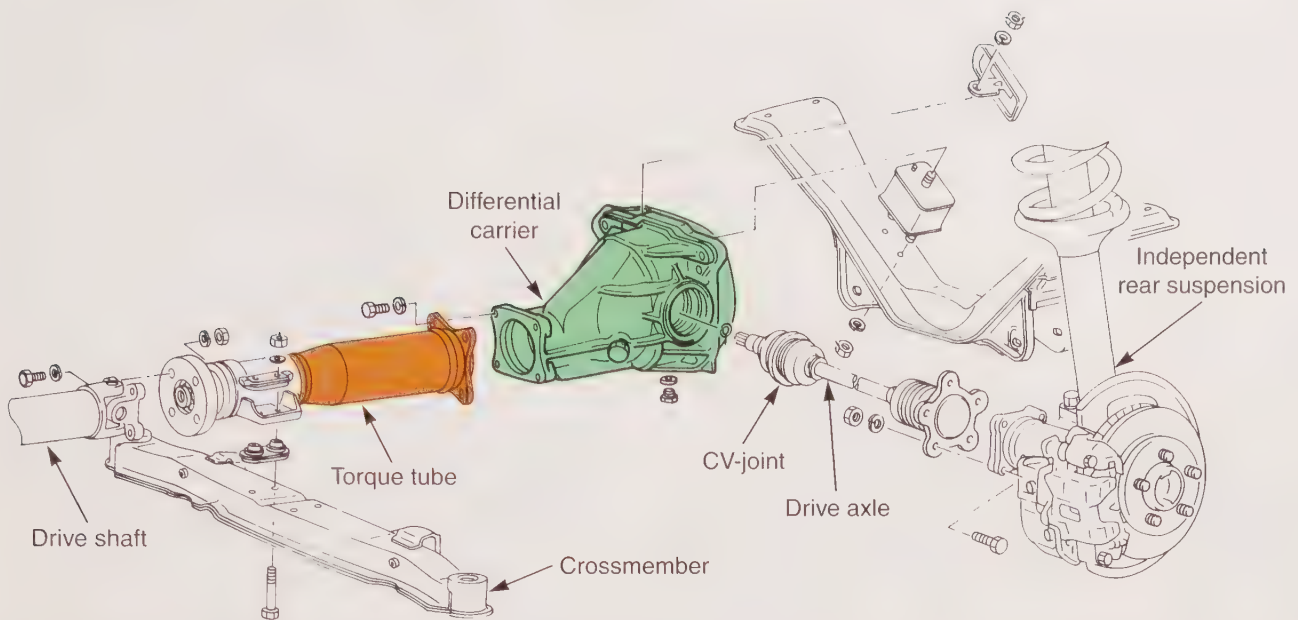


Figure 16-32. The rear axle housing used on vehicles with independent rear suspension has no axle tubes. The carrier has oil seals where the drive axles enter. A torque tube is often used at the front of the housing to increase rigidity and reduce vibration. (Chrysler)

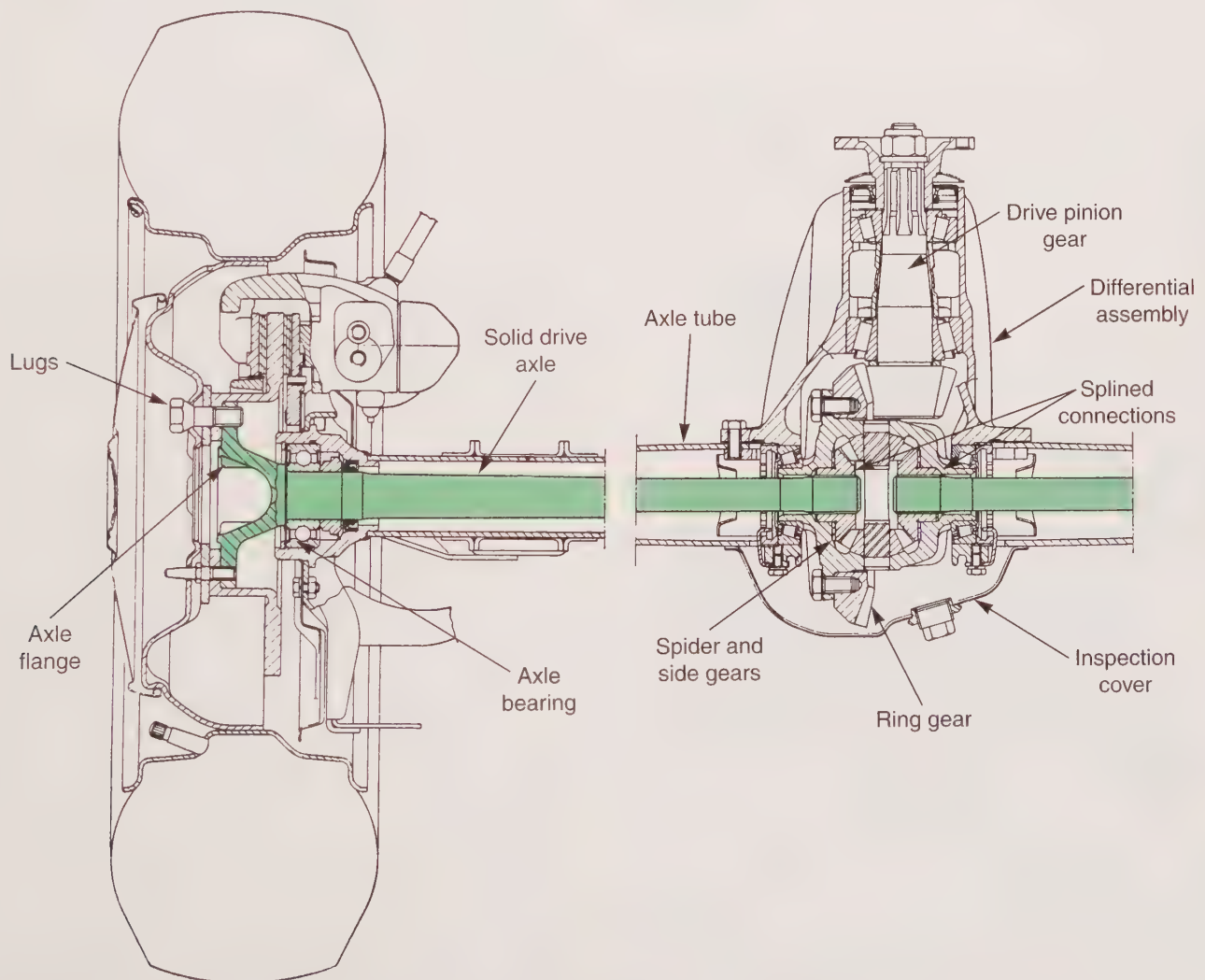


Figure 16-33. The axle shaft used on a solid drive axle, or a live axle, is a single piece of steel that is supported on both ends. The outer support is provided by an axle bearing, and an inner support is provided by the differential side bearings. Note that the differential has been rotated 90° for the purpose of illustration. (Fiat)

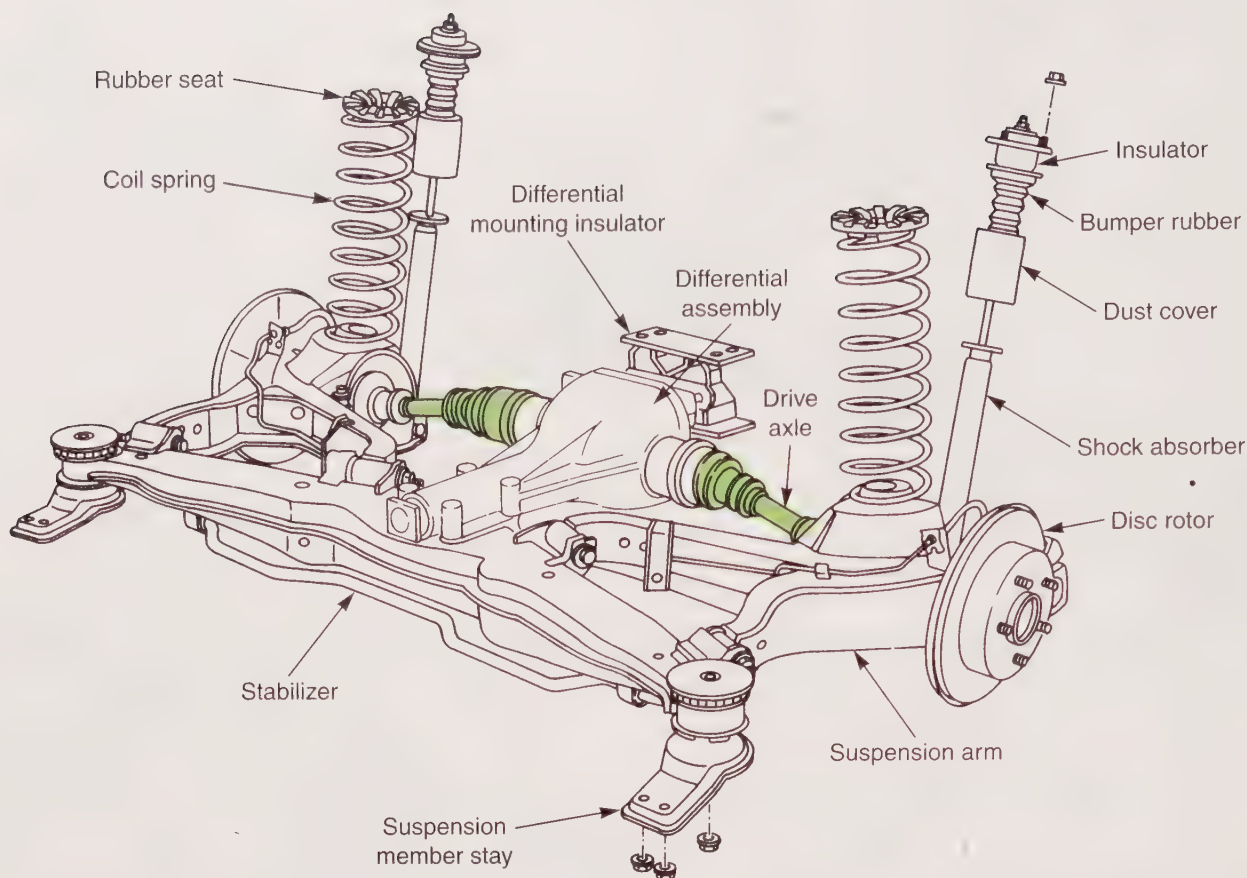


Figure 16-34. Axle shafts used on vehicles having independent rear suspensions somewhat resemble drive shafts. A flexible joint, such as a CV joint, is used on each end of each shaft.

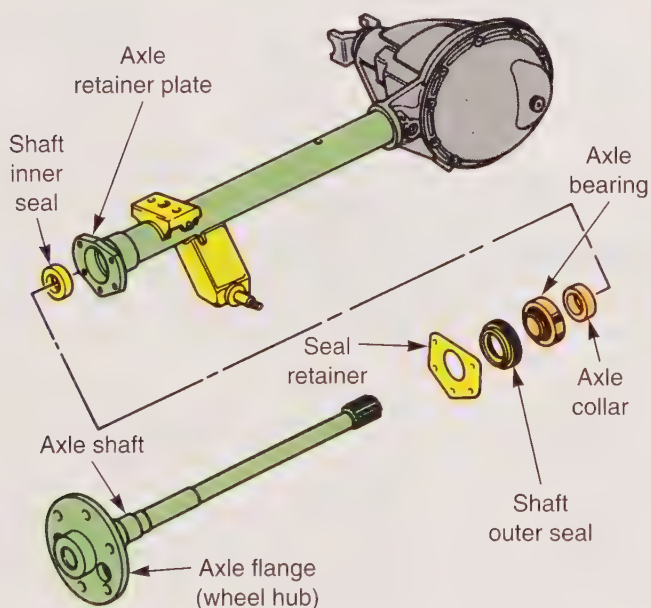


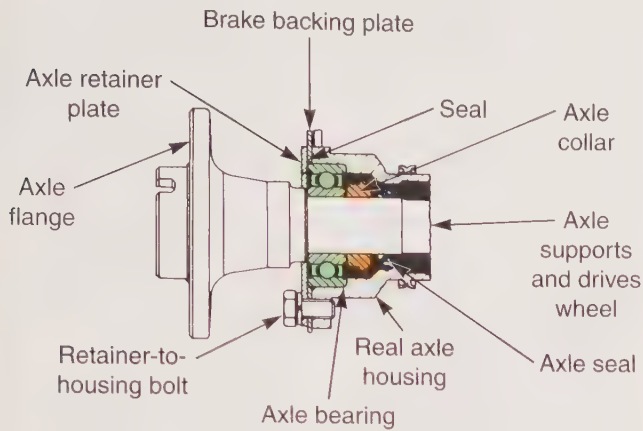
Figure 16-35. Drive axle and related components are shown here. The external splines on the inboard end of the axle mate with the matching internal splines in the differential side gear. The axle flange is a mounting surface for the brake drum or rotor and wheel. The bearing is kept in place by the axle collar. The axle retainer plate keeps the axle and bearing retained in the axle tube. (Chrysler)

through the axle bearing to the drive axle and on to the wheel and tire. **Figure 16-36** shows three versions of the semi-floating axle.

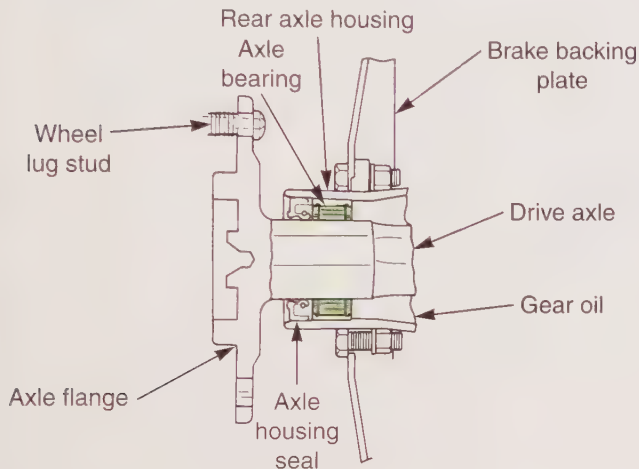
Figure 16-36A shows a semi-floating axle using a ball bearing. This is a pregreased bearing. There is an axle seal behind the bearing. The axle collar is pressed onto the axle shaft. The bearing and axle are held in the housing by an axle retainer plate, mounted on the outer end of the rear axle housing. The retainer plate and bearing control endplay during turns.

Figure 16-36B shows a roller bearing version of the semi-floating axle. This bearing is lubricated by rear end lubricant. The axle seal is installed in front of the bearing. When this kind of bearing is used, the axle is held in the housing by a clip on the inboard end of the shaft, at the differential assembly. This kind of axle is sometimes called a C-lock axle, because of the shape of the locking clip. Endplay on turns is controlled by the fit of the axle shaft between the C-lock and the other parts of the differential assembly.

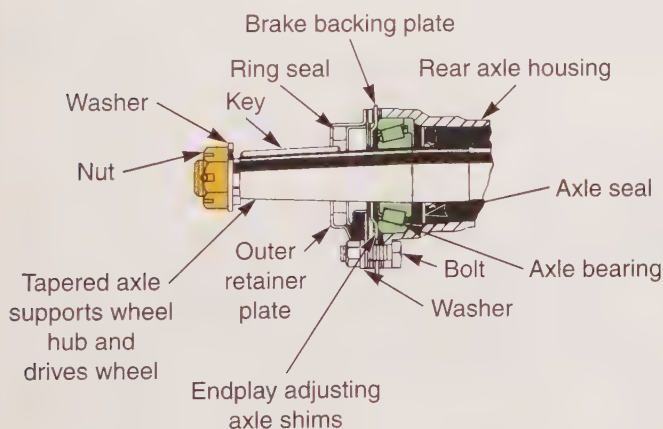
Figure 16-36C shows a semi-floating axle using a tapered roller bearing. This type of axle is usually found on older vehicles. When this type of bearing is used, there is usually some provision for adjusting the bearing preload to control endplay. This is generally done by using **axle shims** or by turning an adjusting nut. Tapered roller bearings may be packed with grease or lubricated from the rear axle



A—Ball bearing semi-floating axle. The ball bearing is retained on shaft by a pressed on axle collar. The bearing and axle are held in the housing by a bolted retainer plate.



B—Roller bearing semi-floating axle. The major difference between this design and that of ball bearing is the shaft locking method. This axle is retained by a C-lock at the inside of the shaft. The C-lock attaches axle to the differential. The bearing plays no part in keeping the shaft in place.



C—Tapered roller bearing semi-floating axle. The bearing preload is adjusted by shims or an adjusting nut. The axle is retained in same manner as ball bearing, except without the axle collar. The shoulder on the axle keeps the axle from sliding past the bearing.

Figure 16-36. The semi-floating axle is the most common shaft and bearing design used on cars and light trucks. The bearing passes the vehicle weight through the axle shaft and out to the wheel. The axle drives and supports the vehicle. (Fiat, General Motors, Deere & Co.)

housing, depending on the particular manufacturer's design.

In **Figure 16-36C**, notice the use of the tapered axle. This is one of two methods used to secure a wheel hub to its axle. The tapered end wedges into a tapered hole in the wheel hub, and the key keeps the axle from rotating in the hub. The other method, mentioned earlier, has the wheel hub (axle flange, in this case) solidly mounted to the axle.

The design of the semi-floating axle causes weight loads to be placed on the axle. These loads will shift as the axle rotates, placing flexing stresses on the shaft. On automobiles and light trucks, the loading is not serious and the axles will usually last the life of the vehicle.

Full-floating axles

If the rear end will be subjected to heavy loads, such as the rear end of a large truck might be, a **full-floating axle** is used. **Figure 16-37** shows an example of a full-floating axle. With this design, the axle drives the wheel but does not carry any of the vehicle weight. The weight passes through the bearings on the wheel hub. The wheel hub absorbs the stresses. This design reduces the stresses on the shaft, prolonging its life. Full-floating axles are not used on light duty vehicles because of their extra cost and complexity.

Independently Suspended Drive Axle

Independently suspended drive axles, used on vehicles with independent rear suspension, resemble miniature drive shaft assemblies. The axle consists of a central shaft with flexible joints and stub axles on each end. The flexible joints—either cross and roller U-joints

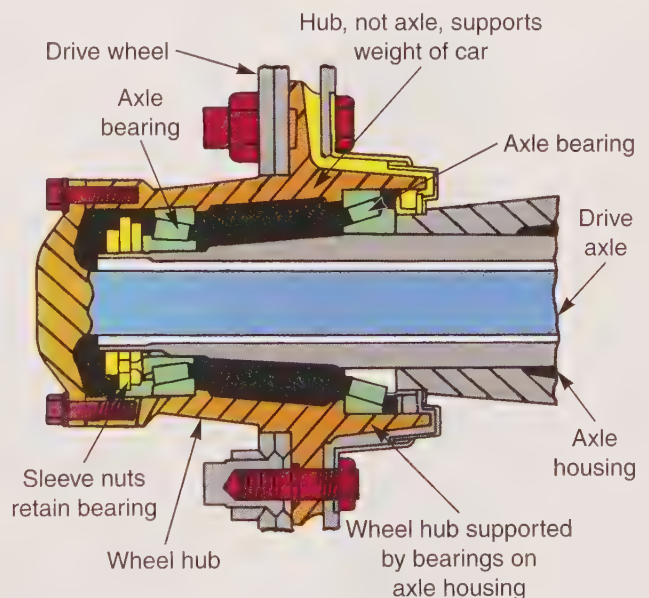


Figure 16-37. The full-floating axle is used on trucks and other vehicles that carry heavy loads. Bearings on the hub transmit the vehicle weight from the rear axle housing to the wheel hub and the wheel without the loading axle. The only job of the axle is to propel the vehicle. (Deere & Co.)

or Rzeppa-type CV joints—allow each wheel to move independently of the vehicle body and of each other.

A typical independently suspended drive axle arrangement is shown in **Figure 16-38**. Although they look different, these axles transfer power in much the same manner as solid drive axles.

Figure 16-39 is an example of how an independently suspended drive axle and wheel hub are assembled. The hub is firmly attached to the suspension control arm. The inner portion of the hub rotates inside of a bearing and acts as a mounting flange for the wheel and brake assembly. The stub axle is splined to the hub and drives it. The universal joint allows free movement of the suspension control arm. Some splined axles can slide to compensate for changes in axle length when the rear suspension moves up and down.

Summary

All rear axle assemblies have the same basic design and operate by the same principles. Rear end variations depend on whether the vehicle has a solid-axle or independent rear suspension, a removable or integral carrier, semi-floating or full-floating axles, and a standard or limited-slip differential.

The major parts of the rear axle assembly are the differential assembly, rear axle housing, drive axles, bearings, and seals. Engine power enters the drive pinion gear through the differential pinion yoke and drive shaft assembly. The drive pinion gear turns the ring gear. The

interaction of the ring and pinion assembly turns the power at a 90° angle and reduces its speed. The ring gear is bolted to the differential case. Power flows from the ring gear into the differential case, which transfers the power to the spider gears. The spider gears transfer the power to side gears, which then transfer the power to the drive axles and rear wheels.

The differential assembly has three purposes. It redirects the drive shaft rotation in a 90° angle, reduces rotating speed to increase power, and allows the vehicle to make turns without wheel hop or axle breakage.

The relative positions of the ring and drive pinion gears must be set exactly, or the gears will be noisy and wear out prematurely. The position of the ring and drive pinion gears in the case and in relation to each other must be carefully adjusted.

The differential case assembly allows the vehicle to make turns without wheel hop. It has an arrangement of gears that allows the rear wheels to turn at different speeds. There are two kinds of differential case assemblies, standard and locking.

The standard differential is composed of meshing spider and side gears, enclosed in a differential case. The ring gear is bolted to the case. Power flow is through the case, into the spider gears, and on to the side gears. The side gears are splined to the drive axles. They transfer power to the drive axles and rear wheels.

When driving on slippery surfaces, the rear wheels of a vehicle with a standard differential will often slip. This is because the differential will always drive the wheel with the least traction. To overcome this problem, various kinds of locking differentials are used. They increase traction by sending power to the wheel with the most traction.

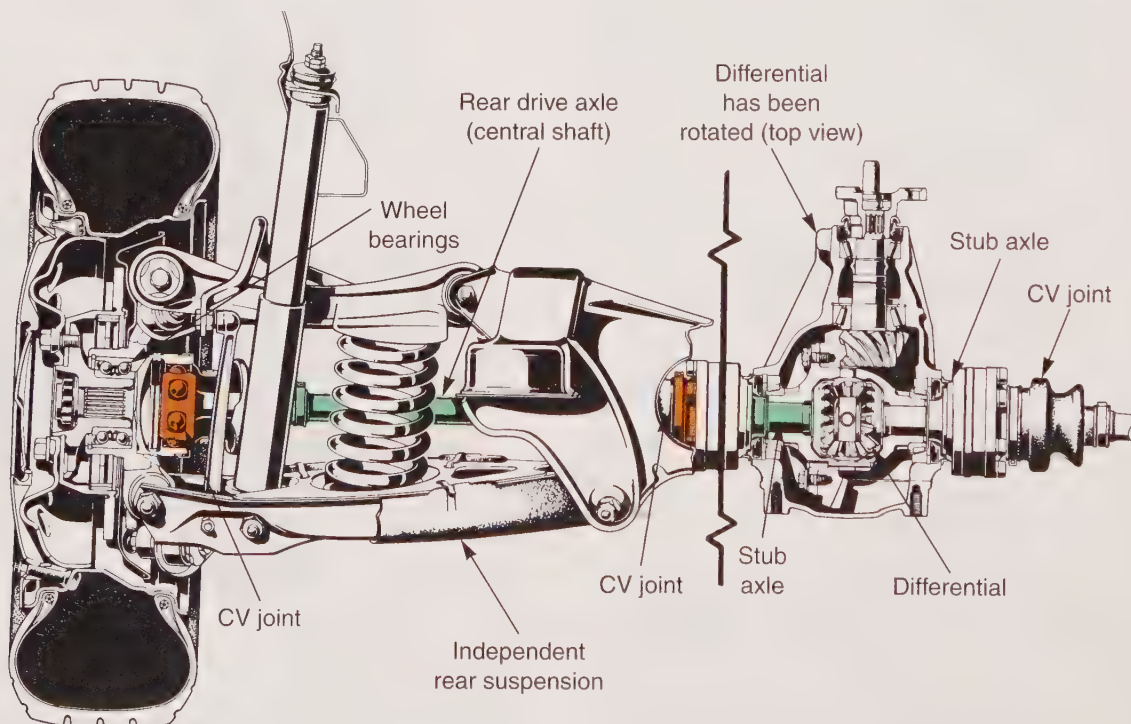


Figure 16-38. The drive axle of a vehicle with an independent rear suspension consists of three shafts and two U-joints. The central shaft is connected through the U-joints to a short shaft, or stub axle, on either side. Stub axles are splined to the wheel hub and side gears. Note that the differential has been rotated 90° for the purpose of illustration.

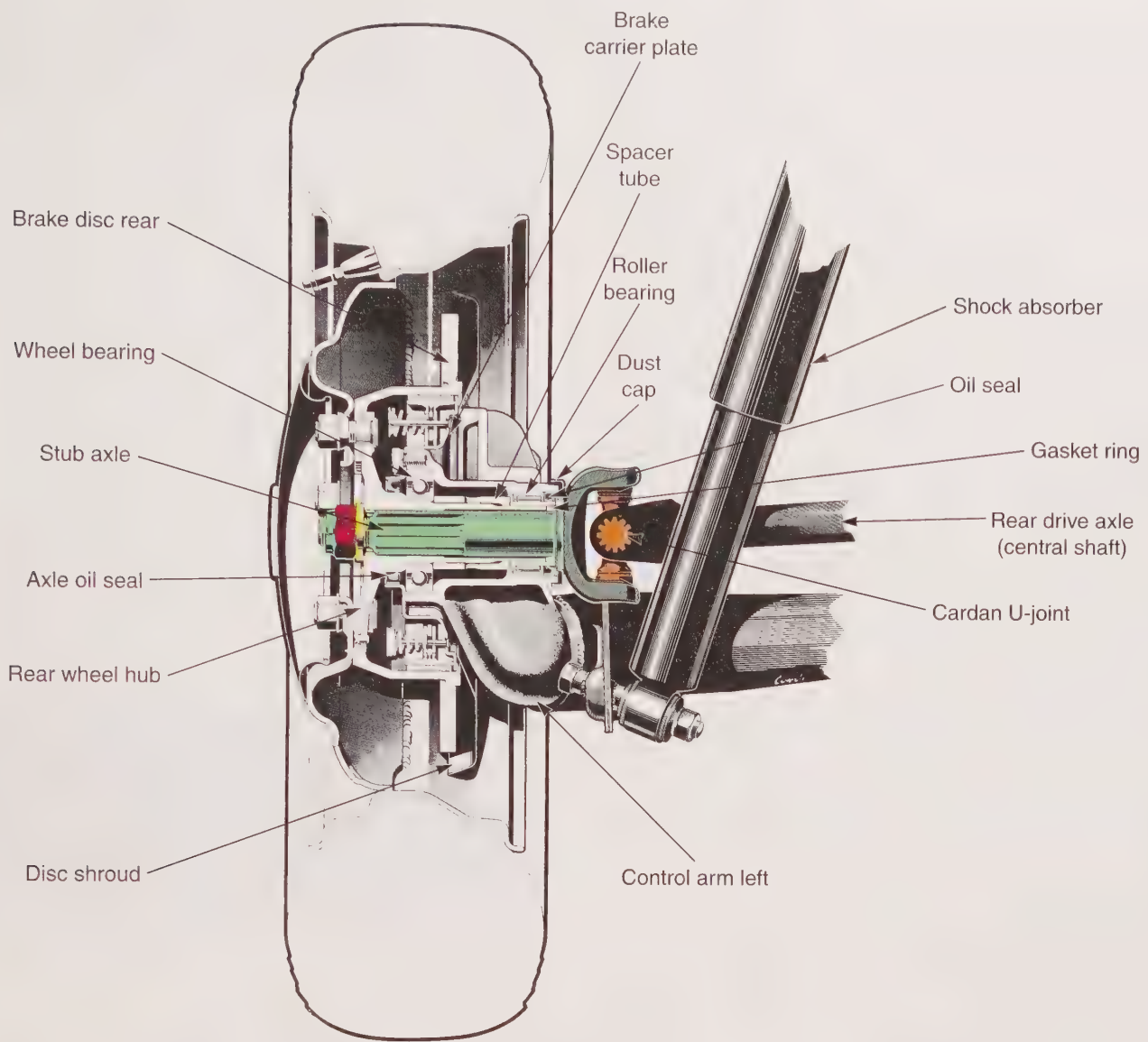


Figure 16-39. This shows how a stub axle and universal joint of an independently suspended drive axle are installed to a hub and wheel of a vehicle with an independent rear suspension. (Porsche)

The most common locking differential is the limited-slip differential. One type uses clutch packs placed between the side gears and the differential case. Friction discs are splined to the side gears; steel plates are dogged to the case. The clutch packs are pressed together by the pressure of the spider gears on the side gears.

When the vehicle is moving straight ahead, the limited-slip differential operates like a standard differential. The rear axle parts turn at the same speed, and the clutch packs are not used. When a wheel starts slipping, the difference in pressure on the side gears causes the clutches to apply. The difference in traction between the inner and outer wheels is not a factor during normal turns, and the friction discs and steel plates slip over each other.

Another version of the limited-slip differential uses cones instead of clutch packs. Operation is similar to the clutch-plate differential.

The ratchet differential has a series of internal cams and ramps that direct power to the wheel with the most traction. Its operation depends on relative wheel speeds, rather than wheel traction. The ratchet differential transfers power through a set of teeth, which can be engaged and disengaged.

The Torsen differential uses an arrangement of worms (drive gears) and worm wheels (driven gears) to transfer power. On turns or when one wheel is slipping, the axle gear and worm wheel arrangement transfers power from the faster wheel to the slower wheel.

The rear axle housing encloses and supports the other parts of the rear axle assembly and forms a reservoir for the rear end lubricant. The rear brake assemblies are usually attached to the rear axle housing. The rear axle housing is attached to the vehicle body by the suspension system.

Two kinds of rear axle housings are used on vehicles without independent rear suspensions. The removable carrier type has all of its moving parts, except the axles, in a carrier

that can be unbolted from the rear axle housing. The integral carrier type is a one-piece unit. It is serviced by removing a sheet metal inspection cover, located at the rear of the housing.

A modified rear axle housing is used on vehicles having independent rear suspension. The internal construction of the housing is identical to those used on live axles. (A version of this housing is used on some front-wheel drive vehicles that have the engine mounted longitudinally.)

The rear drive axles transfer power from the side gears to the rear wheels. Drive axles can be solid or independently suspended. Solid axles are splined with, and supported by, the side gears at the inboard end. The outboard end is supported by axle bearings. The axle bearing can be installed on the shaft or in the housing. Bearings that are installed on the shaft are usually packed with grease. Bearings that are installed in the housing are lubricated by rear end lubricant. Seals are used to keep lubricant from leaking out of the rear axle housing.

Solid axles can be semi-floating or full-floating. In the semi-floating axle, the weight of the vehicle goes through the axle bearing to the shaft and out to the wheel. In the full-floating axle, the axle drives the wheel but does not carry any of the vehicle weight. Most passenger cars have semi-floating axles.

Independently suspended drive axles resemble drive shaft assemblies. They consist of a central shaft with flexible joints and stub axles on each end. The flexible joints can be conventional U-joints or CV joints. They allow each wheel to move independently of the vehicle body and of each other.

Review Questions—Chapter 16

Answer the following questions using the information provided in this chapter.

- Which of the following items does not belong with the others?
 - Rear axle assembly.
 - Final drive.
 - Differential.
 - Rear end.
- What is independent rear suspension?
- Which rear end components change the direction of power flow by 90°?
- How can rear axle ratio be determined?
- If the drive pinion gear has 10 teeth and the ring gear has 35 teeth, what is the rear axle ratio?
- Describe the construction of a drive pinion gear.
- Which of the following parts is used to set pinion bearing preload?
 - Jam nut.
 - Crush washer.
 - Lock washer.
 - Castle nut.

- The convex side of ring gear teeth is the ____ side, and the concave side of ring gear teeth is the ____ side.
- The standard differential is composed of meshing ____ and ____ gears enclosed in a differential case.
- In terms of their construction, what is the major difference between a standard differential and a limited-slip differential?
- The Torsen differential is a locking differential that uses a _____.
 - multiple-disc clutch
 - cone clutch
 - dog clutch
 - worm gearset
- Explain the function of the rear axle housing.
- Describe the two major kinds of carriers.
- In the ____-floating axle, the weight of the vehicle passes through the axle bearing to the drive axle and on to the wheel and tire.
- In a(n) ____-floating axle, the wheel does not carry any of the vehicle weight.

ASE-Type Questions—Chapter 16

- Technician A says that every rear axle assembly has a housing, a differential assembly, and rear drive axles. Technician B says that every rear axle housing has axle tubes. Who is right?
 - A only.
 - B only.
 - Both A and B.
 - Neither A nor B.
- The most common rear axle assembly failures are _____.
 - axle bearing failures
 - pinion yokes failures
 - cracked spider gears
 - stripped ring and pinion gears
- Each of the following is a primary function of the differential assembly *except*:
 - multiplying engine power.
 - allowing the vehicle to make turns.
 - supporting and aligning the drive axles.
 - redirecting power flow to the rear wheels.
- Rear axle ratio can be found by dividing the number of teeth on the ring gear by the number of teeth on the _____.
 - side gear
 - spider gear
 - drive pinion gear
 - axle end gear

5. Each of the following is used to set the pinion bearing preload *except*:
 - (A) a solid spacer.
 - (B) a crush washer.
 - (C) a collapsible spacer.
 - (D) the rear pinion bearing.
6. The ring gear transfers power directly from the drive pinion gear to the _____.
 - (A) axle flange
 - (B) differential case
 - (C) differential carrier
 - (D) differential pinion yoke
7. A rear-wheel drive vehicle cannot be driven because one of its drive wheels is parked on ice. Technician A says that the ring gear and differential case will drive the spider gears. Technician B says that the differential spider gears will walk around the side gear related to the wheel on dry pavement. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
8. Locking differentials overcome traction problems by sending power to _____.
 - (A) the wheel with traction
 - (B) both wheels
 - (C) the slipping wheel
 - (D) the wheel bearings
9. Each of the following is a locking differential *except*:
 - (A) Torsen differentials.
 - (B) ratchet differentials.
 - (C) limited-slip differentials.
 - (D) MacPherson differentials.
10. Each of the following functions is served by the rear axle housing *except*:
 - (A) determining the depth of the drive pinion gear in the carrier.
 - (B) forming a reservoir for rear end lubricant.
 - (C) accommodating suspension system attachment.
 - (D) supporting stationary parts of rear brake assemblies.
11. Each of the following types of drive axles is found on rear-wheel drive vehicles *except*:
 - (A) full-floating axles.
 - (B) Rzeppa axles.
 - (C) semi-floating axles.
 - (D) independently suspended axles.
12. Major differences among rear-wheel drive vehicles with solid-axle rear suspension include each of the following *except*:
 - (A) conventional versus constant-velocity U-joints.
 - (B) removable versus integral carrier.
 - (C) semi-floating versus full-floating axles.
 - (D) standard versus limited-slip differential.



Rear suspension assembly. Note the independently suspended drive axle. (Ford)

Chapter 17

Rear Axle Assembly Problems, Troubleshooting, and Service



After studying this chapter, you will be able to:

- ☐ Identify and describe typical rear axle assembly problems.
- ☐ Explain how to check and verify rear axle assembly troubles.
- ☐ Remove, service, and install drive axles.
- ☐ Remove a removable carrier from a rear axle assembly.
- ☐ Remove an entire rear axle assembly from a vehicle.
- ☐ Explain when rear axle assembly service is necessary.
- ☐ Properly disassemble a rear axle assembly.
- ☐ Check and adjust parts of a rear axle assembly.
- ☐ Install a removable carrier in a rear axle assembly.
- ☐ Assemble and install a rear axle assembly in a vehicle.

Technical Terms

Axle endplay

Ring gear contact pattern

Side bearing preload

Ring gear backlash

Ring gear runout

Machine blue

Introduction

Rear-wheel drive vehicles and a few front-wheel drive automobiles have an axle assembly using hypoid ring and drive pinion gears with a differential case assembly. Although this type of axle assembly is relatively trouble free, it can develop problems and require servicing.

This chapter will acquaint you with the methods of diagnosing and repairing rear axle assemblies. It presents steps in removing, overhauling, adjusting, and installing an entire rear axle assembly. It also includes information on common rear end service tasks, such as axle bearing and seal service.

The information presented here applies to rear axles with solid-axle rear suspension as well as those with independent rear suspension. It also applies to the drive axle assemblies found on front-wheel drive vehicles with conventionally mounted engines. Refer to **Figure 17-1** to see where rear axle assembly problems can occur.

Rear Axle Assembly Problems and Troubleshooting

Major problems in rear axle assemblies are relatively rare. Most internal parts will last for a long time, but once in a while, they will fail. The usual causes of failure are high mileage and abuse. Some parts, such as the axle bearings and seals, will require repairs at some time in the life of the vehicle.

When major problems do occur, it will be obvious the assembly needs repair work. Sometimes, drive axles break because of high shock loads, and no power is sent to the road. Axles held by pressed-on retainers (axle collars) can slide out of the housing due to retainer failure. Ring and pinion gears can be stripped because of high mileage or because of overloading or other abuse. Sometimes, rear axle assemblies will overheat because of improper, or lack of, lubricant or severe overloading.

To begin diagnosis, gather information about the problem. Find out why the vehicle was brought in for service. Test-drive the vehicle—with the owner, if possible. Road test the car on a smooth surface. Use your understanding of operating principles to determine if the problem is actually in the rear axle assembly or if the malfunction is in another system. For example, worn U-joints or transmission gears can produce symptoms similar to those caused by faulty rear axle assembly components.

Unless the rear axle assembly has an obvious problem, such as a cracked housing or severe oil leak, always check the fluid level after the road test. Rear axle assembly lubricant service is discussed following the troubleshooting section. If adding lubricant does not improve the operation of the rear axle assembly, refer to the manufacturer's information.

The most commonly experienced rear axle assembly problems include noises, vibrations, and leaks. These problems are presented in detail in the upcoming paragraphs.

Abnormal Noise

An abnormal noise in the rear axle assembly will be a clunk, whine, roar, or rumble. Before disassembling the rear axle assembly, make sure the problem is not in the clutch, transmission, or drive shaft assembly. Other sources of noise are the front wheel bearings, tires, and brakes. As you diagnose the problem, these must be considered as possible causes.

A defective rear axle assembly may make a clunking noise. This will be a low-pitched, sometimes metallic-sounding, thumping noise. It will occur when the vehicle is first accelerated or when the driver takes his or her foot off the accelerator. Sometimes, the noise will occur during turns or when changing lanes.

A clunking noise will be caused by excessive play between moving parts in the rear axle assembly. Excessive play can be caused by improper ring and drive pinion clearance, side gear and spider gear clearance, or side gear and drive axle clearance. It can also be caused by wear in the differential case, wear of the drive pinion shaft, or worn or improperly adjusted bearings.

The most common cause of clunking noises is improper ring and drive pinion clearance, usually because of wear. However, when the noise occurs upon making turns, it is usually caused by worn spider or side gears or by excessive **axle endplay**, **Figure 17-2**. Clunking noises in the rear axle assembly require the disassembly or removal of the assembly for parts replacement and adjustment.

Whining noises—high-pitched sounds that occur when the vehicle is moving—usually vary with road speed. If a whining noise occurs when driving straight ahead, the problem can be worn or misadjusted ring and drive pinion gears or worn bearings. Worn bearings usually make a lower-pitched sound than worn or misadjusted gears. Whining noises coming from the drive pinion gear are usually higher pitched, since it is rotating at a higher speed than the other rear axle assembly parts.

If the whining noise occurs when accelerating but not when coasting, the rear pinion bearing may be defective. If the whine occurs when coasting but not when accelerating, the problem could be the front pinion bearing. If it seems to change pitch when the vehicle is swerved from side to side, the case or axle bearings could be the cause. If the noise occurs only when the vehicle is making a turn, the spider and side gears are probably the source of the problem. Whining noises usually mean the rear axle assembly must be disassembled so parts can be changed.

Rumbling or roaring noises almost always indicate worn or damaged bearings. The axle bearings at the ends of the axle usually develop these problems. Swerving the vehicle from side to side may cause the bearings to change tone, confirming the problem. If the axle bearing is worn

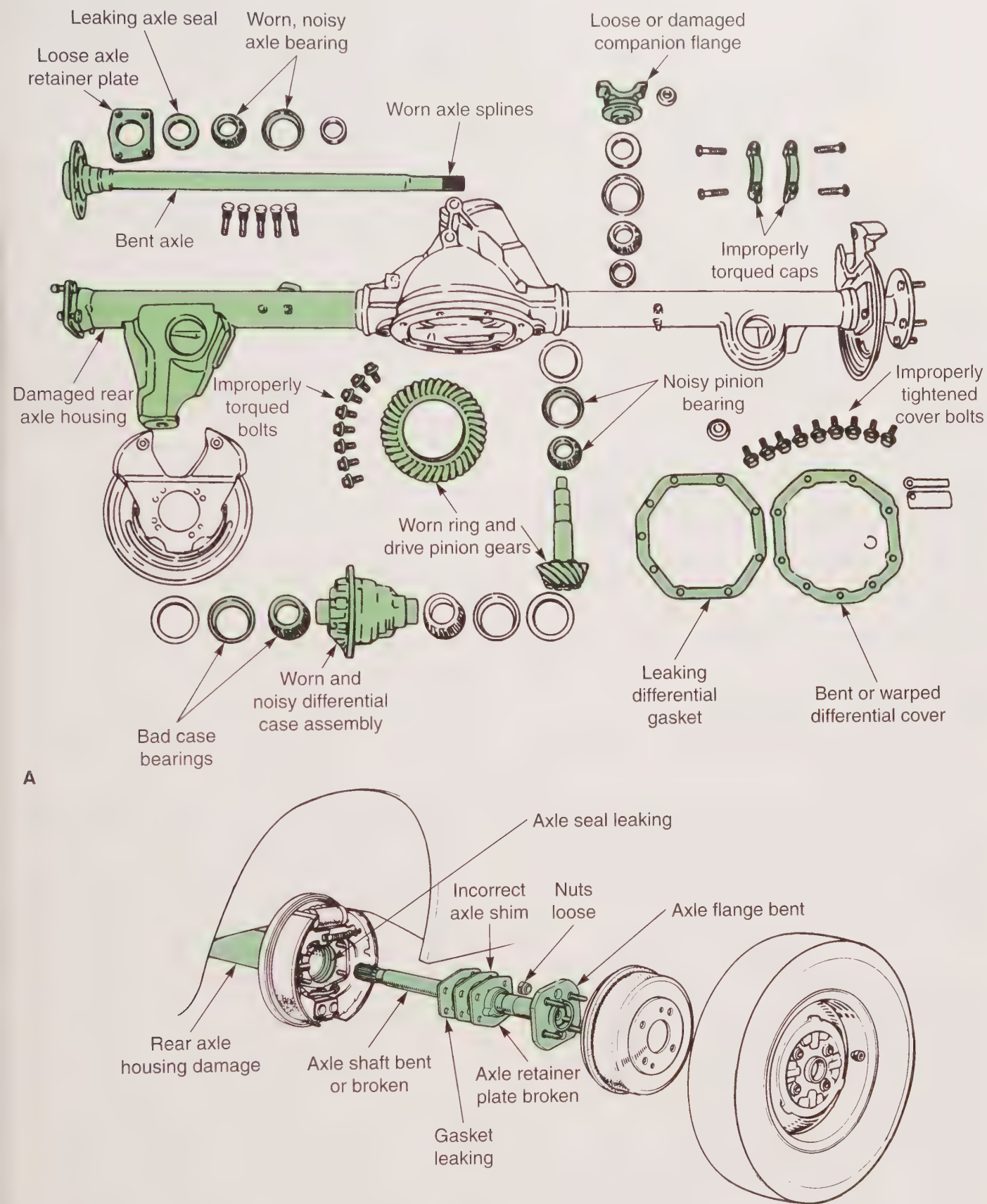


Figure 17-1. The rear axle assembly contains many parts, all of which can become defective. A—This is an exploded view of a complete rear axle assembly. Note where parts may wear out or break. B—Axle bearings and seals often wear out or leak lubricant. (General Motors, Toyota)

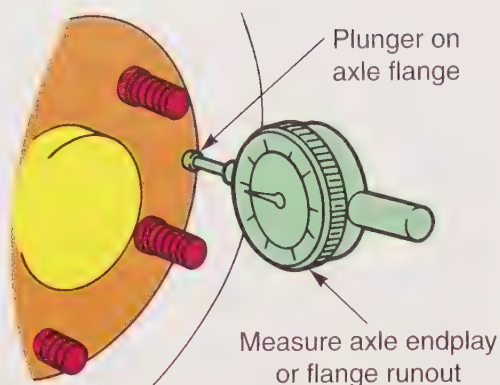


Figure 17-2. Use a dial indicator to measure axle endplay. Mount the indicator so the plunger is parallel with the axle centerline. Push the axle in as far as it will go, and then zero the indicator. Pull the axle out and note the reading on the indicator face. Compare the reading to the factory specs. Note that this setup can also be used to measure axle flange lateral runout. (Ford)

badly enough, it will cause the axle seal to leak. The axle bearings can be changed easily, but replacing the differential bearings requires disassembling the rear axle assembly.

Use a stethoscope to find out where the rear axle assembly noise is coming from. This will help you determine the cause of the noise. For example, a sound that is loudest on the outer end of the rear axle housing will tell you the axle bearing is probably bad.

Rear Axle Assembly Vibration

Rear axle assembly vibrations are high-frequency vibrations that seem to be coming from the rear of the vehicle when it is moving. Vibrations are almost always caused by bent axles or by bent axle flanges, which are usually the result of a severe impact, such as hitting a curb or being hit by another vehicle. To diagnose rear axle assembly vibration, the wheels must first be eliminated as a possible cause of the vibration. This is usually done by switching wheels from the front to rear or by using a dial indicator.

Bent axle flanges can be checked visually or with a dial indicator without removing the axle from the vehicle. The dial indicator will measure axle flange lateral runout. Use the basic setup shown in **Figure 17-2**, but rather than pull out on the axle flange, rotate it and note deviation as you do. Runout should generally not exceed 0.030" (0.76 mm). If it does, the axle flange is bent, and the axle should be replaced.

Bent axles are harder to detect than bent flanges. An axle that is hard to remove from the housing may be bent, but this is not a positive indication. Use a dial indicator to check if the axle is bent. Place the dial indicator between the V-blocks and rotate the axle. As the axle is rotated, measure the radial runout with the dial indicator. If the axle has more than approximately 0.030" (0.76 mm) of runout, it should be replaced.



Warning: Do not try to straighten rear axles. They are hardened and can snap violently!

Lubricant Leakage

Rear axle assembly lubricant leakage is an unwanted loss of fluid from inside the rear axle housing. Lubricant can leak at the pinion seal, the carrier or the inspection cover gaskets, the axle seals, or the oil fill plug. Further, it can leak from cracks in the housing or axle tubes.

Oil can often be seen on the ground under the leak, and it stains the area around the leak, making the leak easier to spot. A leak at the rear axle housing vent may mean the assembly has been overfilled with lubricant. It could also be an indication of water infiltration. Water can enter through the vent if the vehicle is driven through deep water, causing the fluid level to rise to the point of leakage.

Test for the presence of water by dripping some of the oil onto a hot exhaust manifold or by heating it with a match or lighter. Pure oil will smoke; a mixture of oil and water will sizzle.

Some leaks can be repaired easily by replacing the faulty seal or gasket. The pinion seal cannot be replaced without removing the pinion yoke/flange, which means the pinion bearing preload must be reset. If a cracked housing cannot be welded, cracked housings require that the complete rear axle assembly must be disassembled and a new carrier installed.

If the rear axle housing has been overfilled, oil can be drained. If the housing is contaminated with water, it must be thoroughly flushed out and refilled with the proper type of oil.

Limited-Slip Differential Problems and Troubleshooting

The limited-slip differential can develop the same problems as the standard differential, plus some special problems with the limited-slip clutches. Problems related to the limited-slip feature usually occur when the vehicle is accelerating on slippery surfaces or turning a corner. Many of the problems are caused by overloading or by adding the improper oil to the rear axle assembly. Limited-slip differentials require lubricants that contain special additives.

The most common problem experienced by vehicles with limited-slip differentials is chattering or vibration on turns. Sometimes, the rear axle assembly will make a low-pitched moaning noise when the vehicle is turned. These problems are caused by the worn clutches or by use of the wrong oil. Either way, the rear axle assembly must be disassembled, and the clutches must be replaced. Further, if the wrong oil was used, the differential must be completely flushed out and refilled with the proper oil.

If the vehicle fails to drive properly on slippery surfaces, or does not perform any better than a standard differential, the clutches are probably worn. If they are, they should be replaced.

Rear Axle Assembly Lubricant Service

Many automobile manufacturers recommend that rear axle assembly lubricant be checked or replaced at specific intervals. In addition, checking and filling the fluid is important when diagnosing problems in the rear axle assembly.

Fill plugs are located on the inspection cover or on the front side of the differential carrier. The fluid level, with the rear end at its normal position, should just wet the bottom of the fill plug threads. See **Figure 17-3A**. Some manufacturers recommend allowing the fluid level to drop as much as 2" (51 mm) below the plug before adding fluid. If the oil level is too high, the rear axle housing may have been over-filled or the vehicle may have been driven through deep water, allowing water to enter through the vent.

Fluid can be added as shown in **Figure 17-3B**. Always make sure you are adding the proper kind of lubricant. Most modern rear axle assemblies use 80- to 90-weight gear oil. Many trucks and off-road vehicles use oils as high as 140-weight.

Limited-slip gear oil can usually be used in a standard rear axle assembly. Check the manufacturer's service manual to determine the proper lubricant. Do not use engine oil or ATF in a rear axle assembly.

If the rear axle assembly has a limited-slip differential, special limited-slip oil must be used. Never use ordinary gear oil in a limited-slip differential.

Rear Drive Axle Service

Since the ends of the rear drive axles are exposed to the outside, they are subject to more damage than other rear axle assembly components. The axle ends are subjected to flying road debris, snow, ice, and careless handling. Axle flanges can be bent by road hazards, wheel studs can be broken or stripped by overtightening, and the axles themselves may require new bearings and seals. Auto accidents are also a common cause of damage.

There are many kinds of rear axle assemblies installed in modern vehicles. The axle attachment methods and the bearing and seal types are different. Axle lengths and diameters also vary.

It is important that the technician determine exactly what kind of rear axle assembly he or she is dealing with. Most assemblies have an ID tag installed on one of the carrier bolts or on one of the cover bolts. The information on the tag will tell the person at the parts counter what kind of rear axle assembly is installed in the vehicle. If the tag is

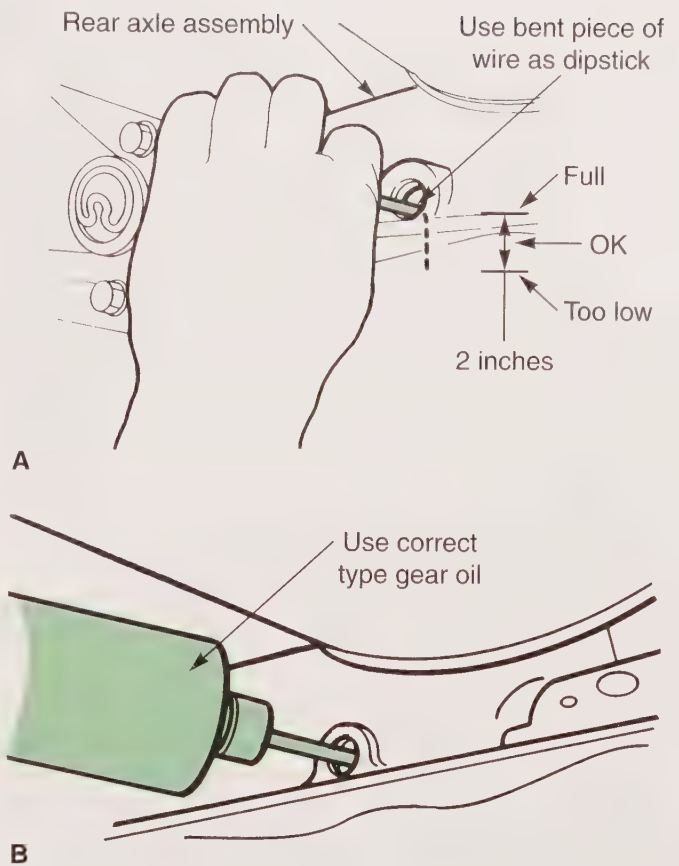


Figure 17-3. Checking and filling lubricant is important when diagnosing rear axle assembly problems. **A**—Fill plugs are usually located on the side of the carrier or on the differential cover. Some rear axle housings will also have drain plugs. **B**—Always use the correct type of oil in the rear axle assembly. Squeeze bottles make oil filling easier. (Ford)

missing, the information may be stamped on the carrier or contained in the VIN on the dash. Sometimes, it is necessary to bring in the old parts so they can be compared to the replacement parts.

Solid Drive Axle Removal

Some solid drive axles are held in the rear axle housing by a retainer plate bolted onto the housing. Other solid drive axles are locked to the side gear by a small clip, or C-lock. Removal methods are different for each type.

Independently suspended drive axles, in most cases, resemble a drive shaft assembly in their installation. These are held in place by one of several methods. Consult the proper service information for exact removal procedures of independently suspended drive axles.

Retainer-type drive axle

The following steps detail the proper way to remove a retainer-type drive axle.

1. Disconnect the battery negative cable.

2. Raise the vehicle on an approved hoist or with a hydraulic jack. Secure the vehicle on jack stands if using a jack.
3. Remove the rear wheel.
4. Mark the brake drum so that it can be reinstalled in the same position, and then remove the brake drum, **Figure 17-4**. If the axle has disc brakes, remove the calliper and rotor.
5. Locate the nuts that hold the retainer plate to the rear axle housing by turning the axle flange by hand. The nuts can be removed by inserting a socket and extension through access holes in the axle flange. Loosen the nuts with a socket wrench. Note that some retainer plate nuts are removed from the back side of the retainer plate.
6. Once the nuts are loose, the flange, axle, retainer plate, and bearing can be pulled out of the housing as a unit. If the axle and bearing stick in the housing, a slide hammer can be used to loosen the axle. See **Figure 17-5**.



Caution: When pulling out the axle, make sure the retainer plate does not hang up on the brake backing plate, causing the backing plate to pull away from the rear axle housing. This could damage a brake line.

C-lock drive axle

The following steps detail the proper way to remove a C-lock drive axle.

1. Disconnect the battery negative cable.

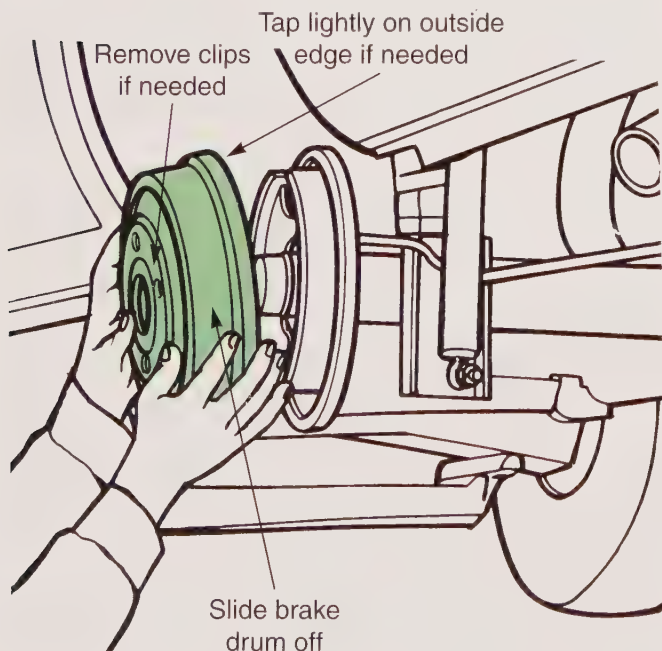


Figure 17-4. After removing the wheel, remove the brake drum. (Ford)

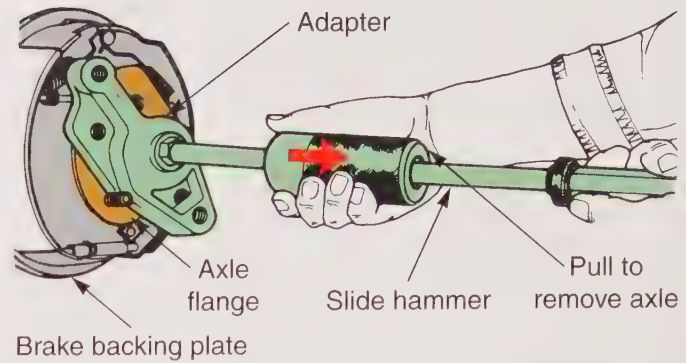


Figure 17-5. Remove the axle with a slide hammer, if necessary. (Chrysler)

2. Raise the vehicle on an approved hoist or with a hydraulic jack. Secure the vehicle on jack stands if using a jack.
3. Remove the rear wheel.
4. Mark the brake drum so that it can be reinstalled in the same position, and then remove the brake drum. If the axle has disc brakes, remove the caliper and rotor.
5. Place an oil pan beneath the differential carrier. Loosen the cover bolts or drain plug and allow the lubricant to drain. Remove the differential cover after the lubricant has drained.
6. Remove the pinion shaft, which holds the spider gears, by unscrewing the lock bolt. Push the shaft out of the differential case. See **Figure 17-6**. You may need to rotate the case so the shaft clears the rear axle housing. The spider gears can be left in place.
7. Push the axle in toward the vehicle. This will allow the C-lock to be removed from the axle. See **Figure 17-7**. In many cases, the C-lock will fall out of position once the shaft is pushed inward.
8. Return the pinion shaft to its location in the differential case and tighten the lock bolt. This will hold the differential gears in place.
9. Pull the axle from the housing, **Figure 17-8**. If the axle sticks, use a slide hammer to loosen it.

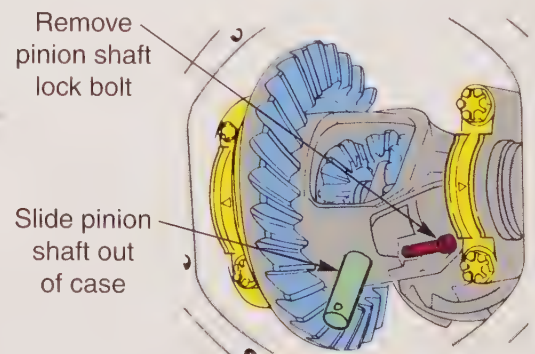


Figure 17-6. To remove a C-lock axle, the pinion shaft in the differential case must be removed. (Ford)

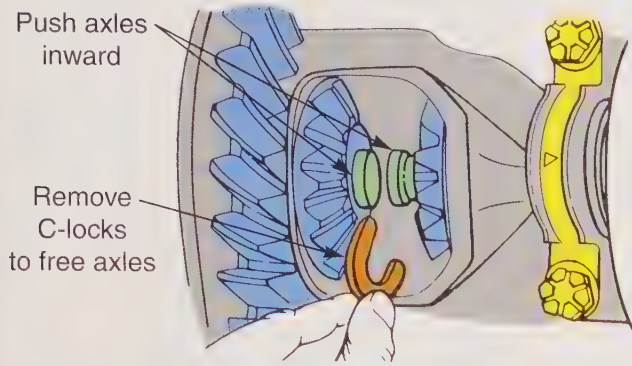


Figure 17-7. Push the axles inward and remove the C-locks. (Ford)

Independently Suspended Drive Axle Removal

Note: The following paragraphs give a general outline of the independently suspended drive axle removal process. Consult the proper service information for exact removal procedures of independently suspended drive axles.

The drive axles used on vehicles with independent rear suspensions resemble small drive shafts or CV axles. Most are attached to the carrier and wheel hubs through bolted flanges at one or both ends. To remove an independent drive axle from the vehicle, begin by marking the mating flanges so that they can be reinstalled in their original positions. Next, remove the fasteners that hold the drive axle flange to the carrier. Then remove the fasteners that hold the drive axle flange to the wheel hubs.

Have an assistant hold the drive axle to keep it from falling while you perform the next steps. If the drive axle uses U-joints, move the wheel assembly outward slightly to separate the flanges and gain clearance for removal. This can usually be done without removing any suspension fasteners. If the drive axle uses CV joints, compress it slightly to reduce its length and separate the flanges. Once one flange is clear of the mating flange, lower the axle to gain clearance and remove it from the vehicle.

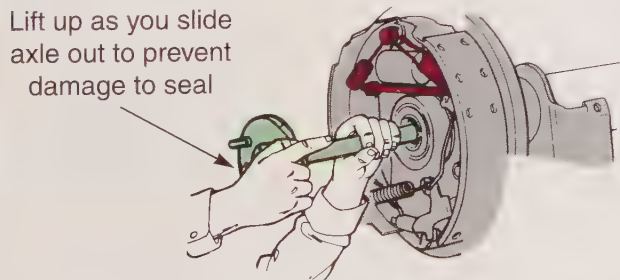


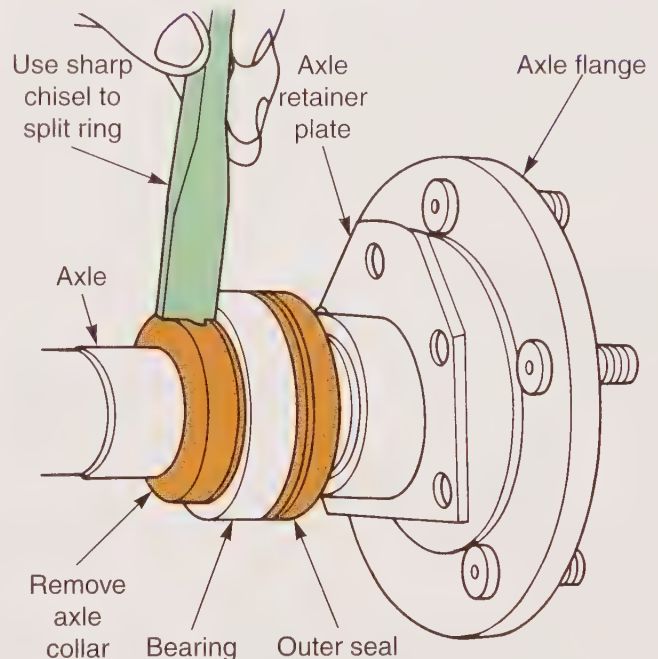
Figure 17-8. Remove the axle from the axle tube. Do not let the axle hang in the tube, as the seal or bearing may be damaged. Do not let the axle splines damage the seal as you remove the axle. (Ford)

Axle Bearing Service

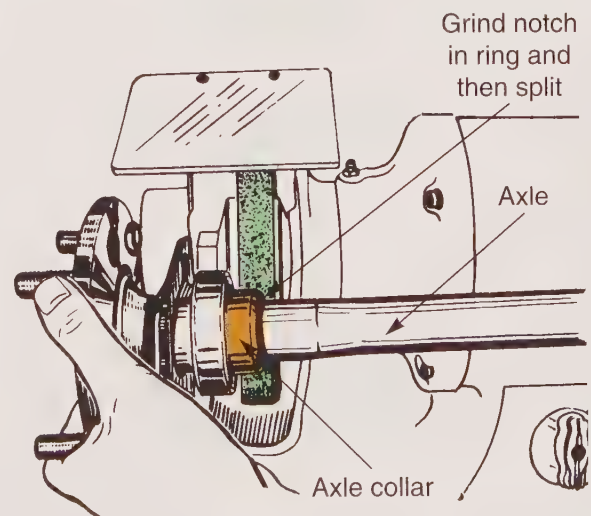
Axle bearings are replaced in different ways, depending on the type of axle. To replace the axle bearings on a retainer-type axle, the axle collar must be removed by breaking it off with a chisel. See **Figure 17-9**. Never remove the collar by cutting or expanding it with a torch. Heat will be conducted to the axle and will ruin it.



Warning: Wear eye protection when breaking an axle bearing or collar off its axle.



A



B

Figure 17-9. Removing the axle collar from a retainer-type axle. A—Remove the collar with a chisel. B—The collar will be easier to remove if a spot is first ground down with a grinder. (Chrysler)

Once the collar is off, the bearing can be pressed off as shown in **Figure 17-10**. Inspect the shaft for damage to the bearing area or to the splines. Decide if it can be reused.

Inspect the new bearing and collar to make sure they match the old parts. The retainer plate can then be reinstalled, and the new bearing and collar can then be pressed onto the shaft. The collar should require approximately 2 tons (4000 psi, or 27.58 MPa) of pressure for proper installation. If it goes on with less pressure, the shaft should be replaced, as it may be worn.

The C-lock axle bearing is installed in the rear axle housing. It can be removed by first removing the seal in the housing and then prying out the bearing. If the bearing is stuck in the housing, you may need a slide hammer with external jaws to remove it.

Before installing the new bearing, check the axle, **Figure 17-11**. If the axle is worn where it contacts the bearing, the axle should be replaced. The replacement bearing should be lubricated and lightly tapped into place. Make sure the bearing seats flush against the mounting shoulder in the rear axle housing.

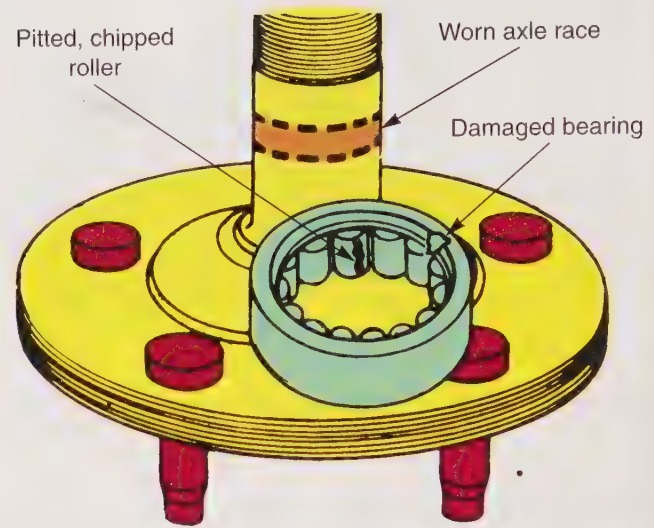


Figure 17-11. Carefully inspect the C-lock axle race or surface that the axle bearing rollers contact. If the axle is worn or damaged where it rides on the bearing, the axle should be replaced. Note that the axle bearing, shown here, is a common source of trouble. The trouble usually arises from an inadequate supply of lubrication. (Ford)

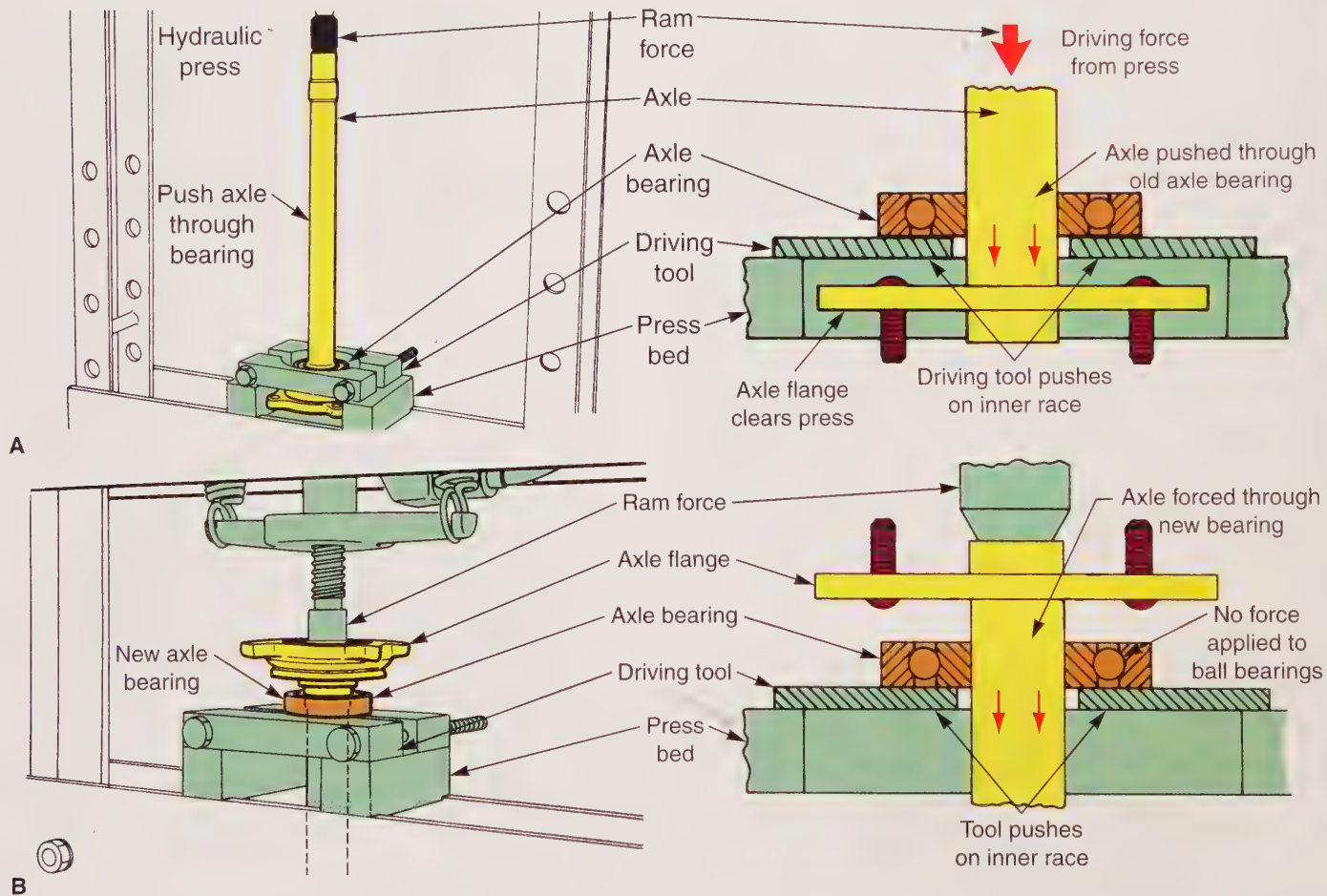


Figure 17-10. Using a hydraulic press to remove and install an axle bearing. A—Pressing off old bearing. Note that the bearing should be supported by a proper bearing adapter so the press can push the axle through the bearing. B—Pressing a new bearing onto the shaft. Press until the bearing bottoms on the axle shoulder. Again, note the use of a proper bearing adapter. (Chrysler)

Wheel Stud Service

The wheel studs are pressed into the axle flange. These threaded studs can be easily replaced if they become broken or stripped. First, remove the wheel and brake drum, marking their original position to maintain balance. Then, drive the defective stud from the flange with a hammer and punch. Do not forget to remove the stud if it falls behind the brake backing plate.

To install the new stud, insert the threaded portion through the hole from the back side of the flange. Push the stud in as far as it will go. Then, install a washer and one of the wheel lug nuts on the stud, as shown in **Figure 17-12**. Tighten the nut. The larger, unthreaded portion of the stud will then be drawn into the flange hole. After the stud is fully seated, remove the nut and washer. Then, reinstall the brake drum and wheel.

This replacement procedure can also be used with the axle removed from the vehicle. However, if the axle is removed from the vehicle, it may be easier to install the new wheel stud with a hydraulic press. Place the stud in the flange hole and, using the proper adapters, press the stud securely into place.

Axle Seal Service

Axle seals should be replaced whenever other axle service, such as bearing replacement, is performed. Seals should also be replaced when they start leaking. The most obvious sign of a leaking axle seal is oil dripping from the brake backing plate. Usually, the back of the tire will also be streaked with oil.

It is important to check the brake linings when replacing a leaking seal. Oil leaking from the seal can be absorbed by the linings, destroying their frictional properties and making the brakes unsafe. Slightly oily linings can be sanded and returned to service, but soaked linings should be replaced.

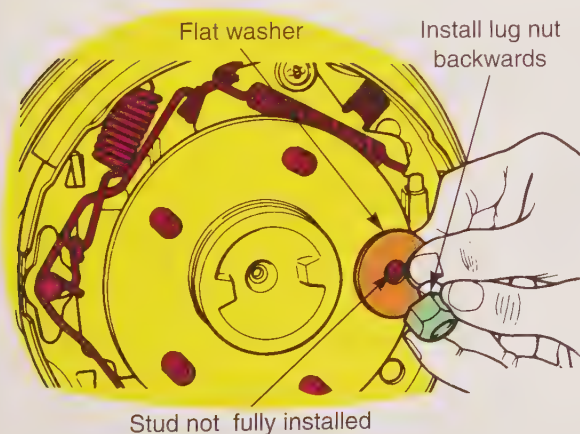


Figure 17-12. A new wheel stud can be installed on a wheel flange by tightening it into place with a lug nut. A washer should be installed temporarily to distribute pulling force and ensure the stud is completely installed. (General Motors)

The axle seal can be removed by first removing the axle, as discussed earlier. The seal can then be removed by prying with a screwdriver or other tool, or removing it with a slide hammer equipped with external jaws. Do not gouge the inside of the rear axle housing.

Before installation, check the new seal for proper fit in the axle tube bore and on the axle. Some seals are precoated with sealant on their outside diameter. If the seal is not precoated, a light coat of nonhardening sealer should be placed around the outside diameter. The seal can then be driven into place with a seal driver.

Figure 17-13 shows a typical seal replacement procedure. If you do not have the proper driver, be extra careful so the seal is installed without damaging it. Do not dent or bend the seal.

The seal should be installed so that it is square with the axle tube bore. There is usually a shoulder for the seal to bottom against. Before installing the axle, lightly oil the lip of the seal with the proper kind of lubricant. When installing the axle, make sure you do not drag it across the seal.

Solid Drive Axle Installation

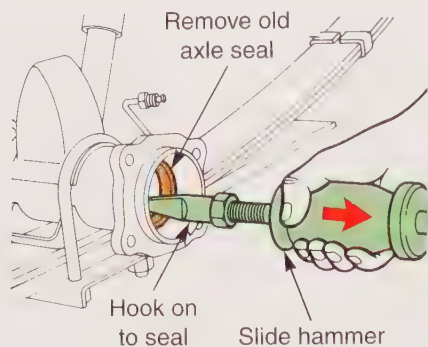
The general procedures for installing solid drive axles are presented in the following section. Exact procedures vary, but basically it is the reverse of removal. You should always refer to the manufacturer's service manual for specific installation procedures—for solid or independently suspended drive axles.

Retainer-type drive axle

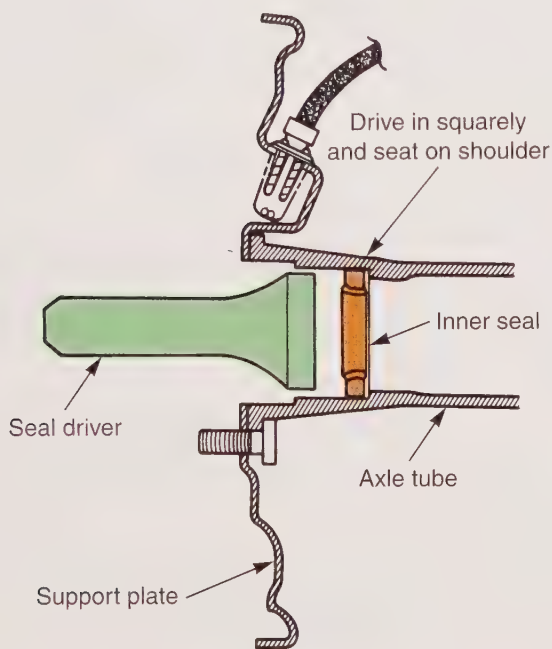
The following steps detail the proper way to install a retainer-type drive axle.

1. Raise the vehicle on an approved hoist or with a hydraulic jack. Secure the vehicle on jack stands if using a jack.
2. Remove the brake backing plate momentarily and check the axle tube flange to see that the surface is clean and free of old gasket material. Install bolts through the flange. Then, place a new gasket over the flange.
3. Position the brake backing plate and brake assembly over the gasket and flange. Position the outer gasket over the brake assembly.
4. Lubricate the splines on the drive axle with proper lubricant.
5. Install the drive axle into the axle tube, being careful not to damage the axle seal. Engage the axle splines with the side gear splines, pushing the axle in as far as it will go.
6. Position the axle retainer plate over the axle tube flange bolts. Install nuts over the bolts and torque them to the manufacturer's specifications.
7. Check axle endplay and adjust if necessary. (Refer to **Figure 17-2**.)

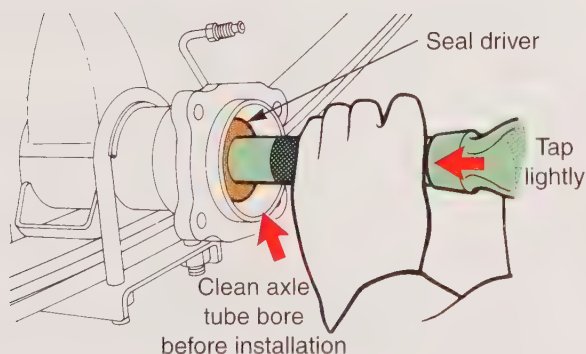
8. Install the brake drum or rotor caliper, and install the rear wheel.
9. Lower the vehicle. Check the brakes. Test-drive the vehicle to ensure proper operation.



A



B



C

Figure 17-13. Axle seal replacement. A—The old seal is removed with a special puller. Sometimes, the seal can be removed with a prying tool, but care must be taken not to damage the housing. B—The new seal (shown here as a sectional view) should be installed with a seal driver that matches the seal diameter. C—Gently tap the new seal into place. (Chrysler)

C-lock drive axle

The following steps detail the proper way to install a C-lock drive axle.

1. Raise the vehicle on an approved hoist or with a hydraulic jack. Secure the vehicle on jack stands if using a jack.
2. Remove the lock bolt or pin and the pinion shaft from the differential case assembly.
3. Lubricate the splines on the drive axle with proper lubricant.
4. Install the drive axle into the axle tube, being careful not to damage the axle seal. Engage the axle splines with the side gear splines, pushing the axle in until the end extends past the side gear.
5. Insert the C-locks in the grooves in the axle. Pull the axle outward to seat the C-locks.
6. Install the pinion shaft and lock the bolt or pin. Torque the bolt to proper specifications.
7. Check axle endplay and adjust if necessary. (Refer to **Figure 17-2.**)
8. Scrape off any old gasket material from the differential cover and its mating surface on the rear axle housing. Install a new gasket and use a nonhardening gasket sealer. Note that some manufacturers recommend using form-in-place gaskets. The bead of this type of gasket should be laid evenly and should completely encircle all bolt holes.
9. Tighten the differential cover bolts in a crisscross pattern. Torque the bolts to the manufacturer's specification.
10. Add the proper type of rear axle assembly lubricant. Replace the fill plug and torque it to specifications.
11. Install the brake drum or rotor caliper, and install the rear wheel.
12. Lower the vehicle. Check the brakes. Test-drive the vehicle to ensure proper operation.

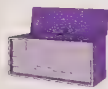
Independently Suspended Drive Axle Installation



Note: The following installation process assumes that the drive axles are attached through flanges that are bolted together. Refer to the proper service information for specific procedures.

An independent suspension drive axle can be installed without removing other rear suspension parts. To begin installation, ensure that the mounting flanges are clean and have no burrs, dents, or other damage that would prevent proper mating of parts. Clean the flanges and use a hand file to remove any burrs. If the flanges cannot be repaired, replace them. Next, place the drive axle inner flange in

position on the differential carrier and align the match marks made before removal. Then, install the fasteners but do not tighten them at this time.



Note: Some manufacturers specify the use of new fasteners when reinstalling axles. Consult the service literature before reusing the old fasteners.

If the drive axle uses U-joints, move the wheel assembly outward slightly to gain enough clearance to install the outer drive axle flange to the wheel flange. This can usually be done without removing any suspension fasteners. If the drive axle uses CV joints, compress it slightly to reduce its length and place the axle and wheel flanges in position. Align the match marks and loosely install the fasteners. Once all fasteners are started, begin tightening the fasteners on one flange in a cross or star sequence, making sure that the flanges pull together evenly and are flush with each other when all fasteners are tightened. The gap between the flanges should be the same on all sides of the flanges. Repeat the tightening procedure on the other flange. Finish by tightening the fasteners to the proper torque using a torque wrench. It is critical that the fasteners be properly torqued to prevent damage or injury.

Differential Assembly Service

This section covers the removal, repair, and reinstallation of differential assemblies. Since differential assemblies are not frequently repaired, it is difficult to build up a body of experience. This section will help you learn the steps involved in repairing a differential assembly so that you are ready to repair one when the time comes.

Differential Assembly Inspection

Before removing and disassembling the differential, check for problems while it can still operate. This is not possible in cases of severe damage, such as with stripped gears or broken shafts, but it will be helpful in other cases to confirm a diagnosis.

To check the differential assembly, raise the vehicle so that both rear wheels are off the ground and free to rotate. Ensure the vehicle is solidly supported and cannot work its way from the lift or jack stands. Start the engine and place the transmission in gear. Then, listen for noises. A stethoscope can be used to pinpoint the exact location of the noise.



Warning: Be extremely careful when working around the turning wheels and drive shaft. Cover long hair and do not wear loose clothing. Never touch spinning parts with your stethoscope!

As an additional check, pull the parking brake cable on one side while the engine is still running. This will stop one wheel while allowing the other wheel to turn. Do the same on the other side. This procedure may isolate the problem to one side or the other.

An additional check can be made on limited-slip differentials. The wheels do not have to be removed. The vehicle should be raised so only one rear wheel is off the ground. Do *not* start the engine, and make sure the transmission is in Neutral. Attach a torque wrench to the raised wheel using an adapter, as shown in **Figure 17-14**. Try to turn the axle with the torque wrench.

The axle should break away, or begin to move, when the torque reading approaches approximately 30 ft lb (41 N•m). This value is determined by the pressure on the clutch pack due to the preload spring(s). The clutch pack begins to slip when applied torque exceeds this value. The torque reading can be higher than 30 ft lb, but it should not be much lower. Improper rear end lubricant could be responsible for a low reading. If the reading is lower, the clutches will need to be replaced. Note that once the axle starts turning, the torque reading will be reduced. This is normal, as long as the torque remains constant through a full revolution of the axle.



Warning: Do not start the engine and place the transmission in gear with one wheel on the ground. The limited-slip differential will attempt to drive the wheel on the ground, possibly causing the vehicle to be driven off the lift or jack stands.

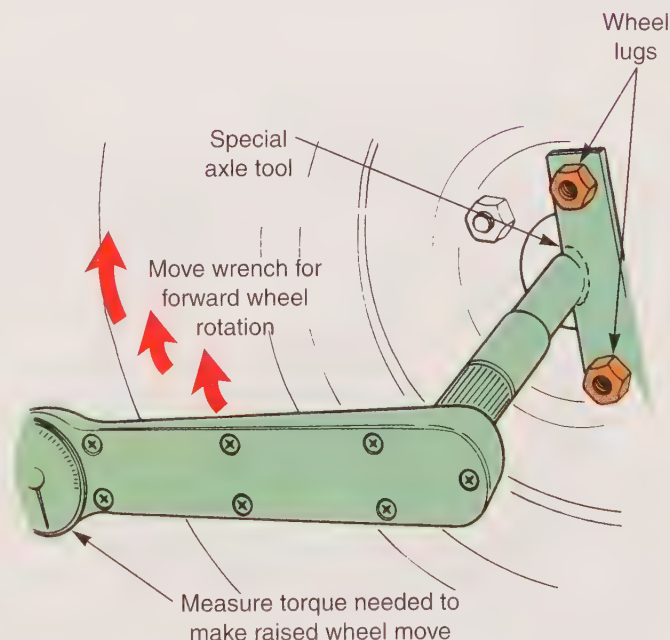


Figure 17-14. A limited-slip differential can be checked with a torque wrench. The wrench is attached to the raised wheel with a special adapter. The other wheel should be on the ground. If the torque is lower than specified, the clutches are worn out or the wrong lubricant has been used. (Ford)

Finally, if the differential is the type that has an integral carrier, remove the inspection cover and closely inspect the rear axle assembly lubricant for the presence of metal particles or for presence of water. This will give you a clue to possible internal problems. Then, the gears can be thoroughly cleaned with solvent, **Figure 17-15**.

After the cleaning process, inspect the ring and drive pinion for wear and for excessive play between the gears. Check the pattern of wear. Typical **ring gear contact patterns** are shown in **Figure 17-16**. Most of the problem areas will be caused by incorrect adjustment. Even if the contact pattern is correct, the teeth may be excessively worn or pitted. Also, check for wear on the spider and side gears and for excessive play between them or for other obvious problems.

Differential Assembly Removal

The exact procedure for differential assembly removal varies according to the type of differential. Differential assemblies with removable carriers are easier to remove from the vehicle, since the entire rear axle assembly does not require removal. If the differential carrier is the integral type, it is normally easier to leave the unit installed in the vehicle for service. However, it is usually harder to work on the internal components while under the vehicle.

The procedures for removing a differential assembly from a vehicle with independent rear suspension are similar to those for solid-axle rear suspension. However, there are still differences between them. **Figure 17-17** shows some of the components that must be disconnected to remove a rear axle assembly using independent rear suspension.

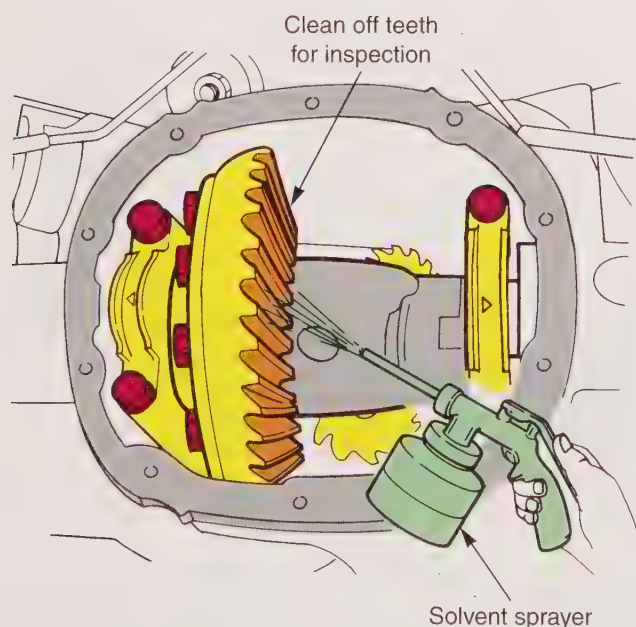


Figure 17-15. To inspect rear axle assembly parts, they must be thoroughly cleaned. Use a petroleum-based solvent and air dry. Never clean any parts with water. (Ford)

Removable carrier

The following procedure details the proper way to remove a differential assembly from a rear axle assembly having a removable carrier.

1. Disconnect the battery negative cable.
2. Raise the vehicle on an approved hoist or with a hydraulic jack. Make sure it is properly supported.



Warning: Use jack stands to support the vehicle. Do not use boxes or concrete blocks. Failure to support the vehicle properly could cause damage or personal injury.

3. Remove the rear wheels.
4. Mark the brake drums so that they can be reinstalled in the same position, and then remove them.
5. Remove the nuts that hold the axle retainer plates to the rear axle housing. (Most drive axles of rear axle assemblies with removable carriers are secured with retainer plates.)
6. Pull the axles approximately 1' (25 cm) out of the rear axle housing (or remove them completely).
7. Mark the drive shaft assembly for proper reinstallation and remove it.
8. Remove any hardware, such as brake line brackets, attached to the carrier.
9. If the carrier has a drain plug, remove it and allow the oil to drain.
10. Support the carrier on a jack stand. Then, loosen the nuts holding the carrier to the rest of the rear axle housing and pry the carrier away from the housing. Allow the oil to finish draining.
11. Remove the nuts and, with at least one other person to assist you, slide the carrier away from the housing and lower it to the floor. See **Figure 17-18**.



Warning: A cast iron removable carrier is surprisingly heavy for its size. Be ready to support its weight during removal.

Integral carrier

For convenient access to a differential assembly having an integral carrier, it is sometimes better to remove the entire rear axle assembly. **Figure 17-19** shows some of the hardware that must be removed to accomplish this. The following procedure details the proper way to remove the rear axle assembly of a vehicle with either solid-axle rear suspension or independent rear suspension.

1. Remove the battery negative cable.
2. Raise the vehicle on an approved hoist or with a hydraulic jack. Make sure it is properly supported.

Checking and Adjusting Gear Tooth Contact Pattern

Drive Side

Coast Side

Correct Mesh

The contact pattern is uniformly distributed over both tooth faces: drive and coast.

Incorrect Mesh

Drive side: Contact on top of tooth and toward center.

Coast side: Contact on heel of tooth and toward center.

Move ring gear away from pinion, using thinner side bearing shim.

Incorrect Mesh

Drive side: Toe contact, localized at root.

Coast side: Heel contact, localized at root.

Move pinion away from ring gear, using thinner drive pinion gear shim.

Incorrect Mesh

Drive side: Heel contact, toward center of tooth.

Coast side: Toe contact, toward center of tooth.

Move ring gear closer to pinion, using thicker side bearing shim.

Incorrect Mesh

Drive side: Heel contact, localized on crest of tooth.

Coast side: Toe contact, localized on crest of tooth.

Move pinion closer to ring gear, using thicker drive pinion gear shim.

Figure 17-16. This chart shows typical ring gear contact patterns, which show patterns of tooth wear. The chart can be used to determine what must be done to repair the rear axle assembly. Worn gears cannot be fixed by readjustment. (Peugeot)

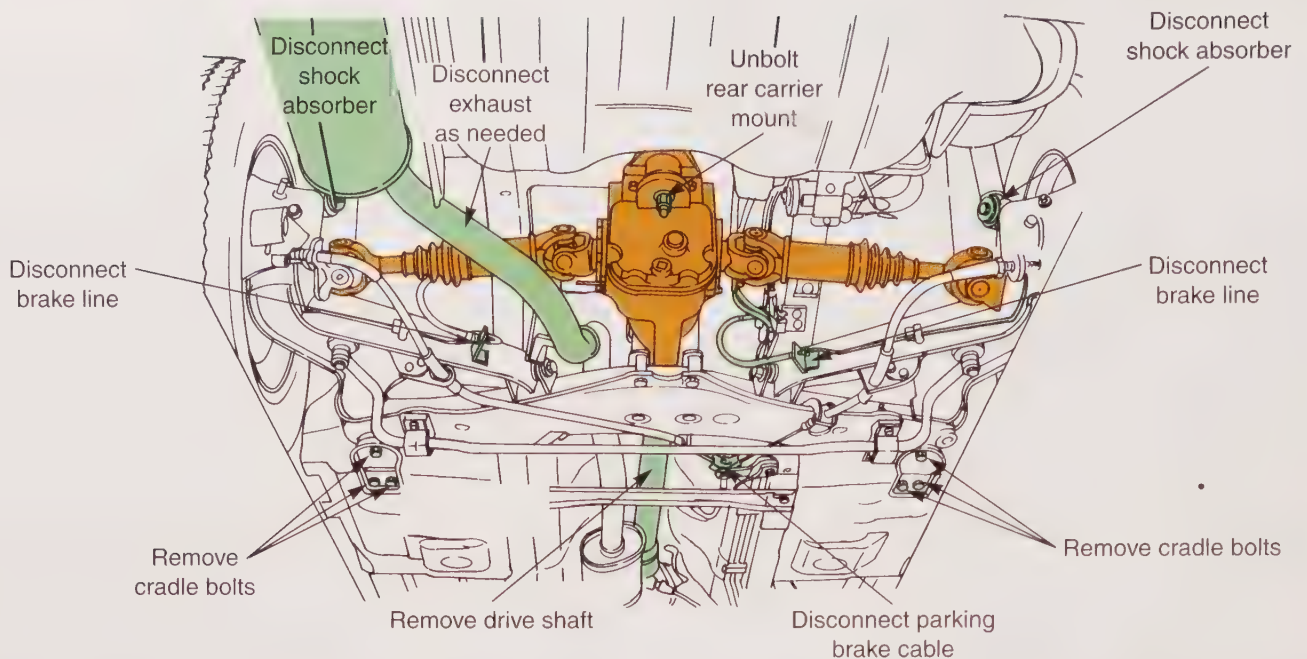


Figure 17-17. To remove a rear axle assembly, other vehicle attachments and hardware must be disconnected. This shows the typical components that must be disconnected to remove a rear axle assembly used with an independent rear suspension. (Subaru)



Warning: Use jack stands to support the vehicle. Do not use boxes or concrete blocks. Failure to support the vehicle properly could cause damage or personal injury.

3. Remove the rear wheels.
4. Remove the brake drums if there is a danger of them falling off the axle flanges. If not, they can be left installed. Mark the brake drums, if they are removed, so they can be properly installed.
5. Mark the drive shaft assembly for proper reinstallation and remove it. See **Figure 17-20**.
6. Raise the rear axle housing slightly and support it with a floor jack or a transmission jack, as required. This will remove the tension from the springs and allow the

attaching hardware to be removed. It will also keep the rear axle assembly from dropping once attaching hardware is removed.



Warning: All tension should be removed from the rear suspension springs before the spring attaching bolts are removed. These springs are very powerful, and they can cause personal injury or serious equipment damage.

7. Remove the shock absorbers and spring attachments. Leaf springs are usually attached to the housing by U-bolts. Leaf springs will fall free once the U-bolts are removed. Coil springs are usually held in place by the weight of the vehicle and the travel limits of the shock absorbers. Coil springs will fall free once the shocks are removed and the rear axle assembly drops down far enough. Make sure the springs do not fall on you or anyone else.
8. Remove any stabilizer bars or other stiffening bars and any strut arms. (Strut arms, sometimes called track bars, are usually used with coil spring systems and are located between the vehicle body and housing. Refer to **Figure 17-19**.)
9. Disconnect the brake lines and parking brake cables. Cap the brake lines to retain as much of the brake fluid as possible.
10. Remove the exhaust pipes if they pass below or close to the rear axle housing.
11. If the rear axle assembly is part of an independent rear suspension, remove the drive axles. See **Figure 17-21**. Also, most independent rear suspension systems use a cradle to hold the assembly in place. It should be

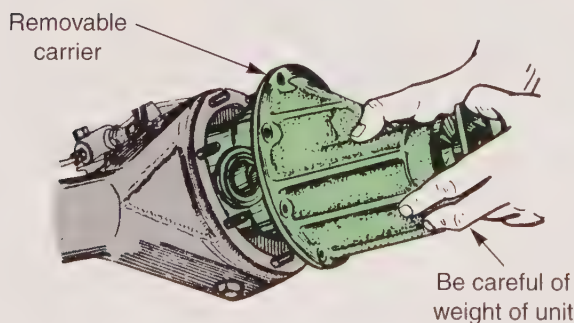


Figure 17-18. Slide the removable carrier back and lower it. The carrier is very heavy. Have a helper assist you and be ready to support the carrier's weight. (Chrysler)

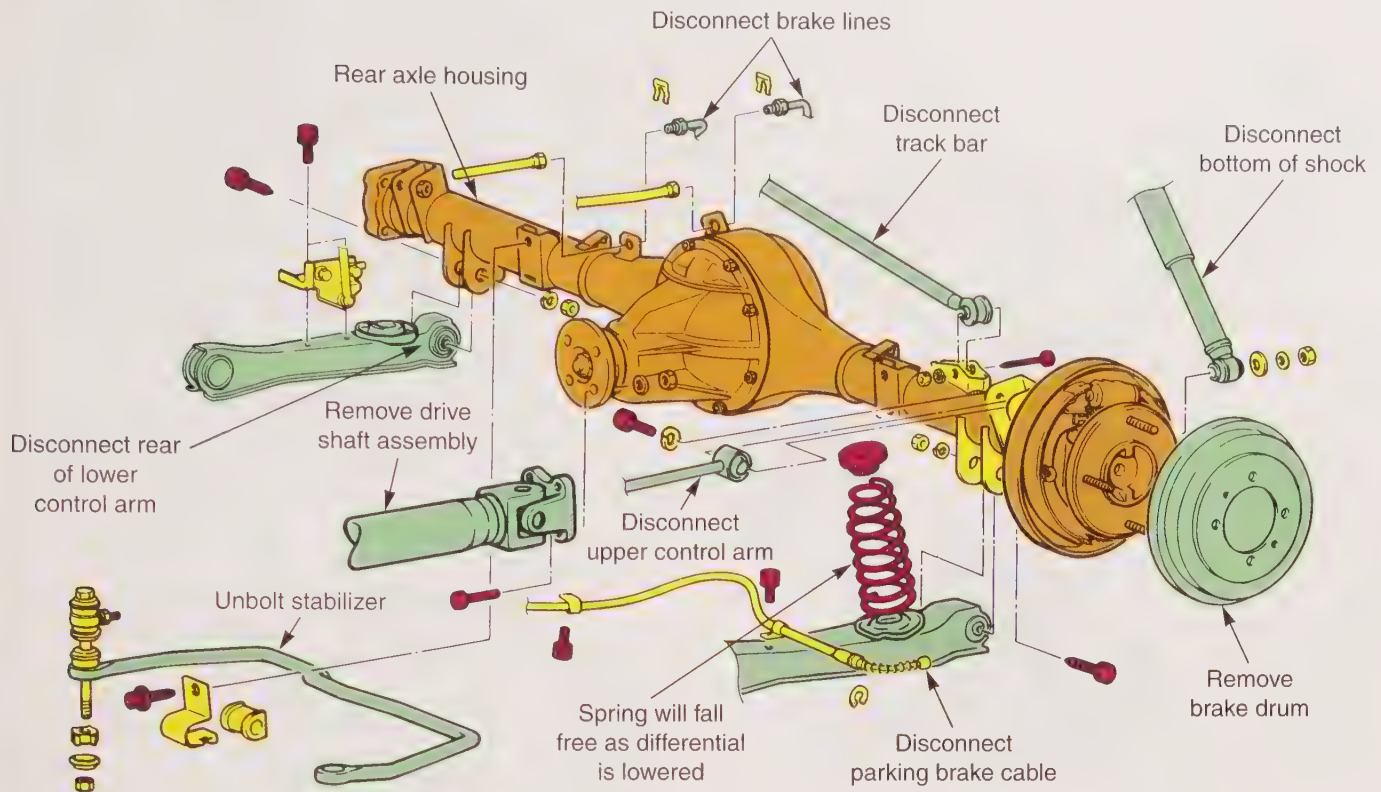


Figure 17-19. A typical solid drive axle is shown here. Note the parts that must be disconnected from the rear axle housing before it can be removed. Note that this assembly has a removable carrier, and it may not be necessary to remove the entire housing. (Chrysler)

unbolted, along with the rear differential carrier mount, after all other attachments are removed. In a few instances, the entire assembly—differential carrier, drive axles, and cradle—are removed as a unit. (Refer to **Figure 17-17**.)

12. Once all attachments have been removed, carefully lower the rear axle assembly from the vehicle, **Figure 17-22**. The oil does not have to be drained until the axle assembly is on the bench.

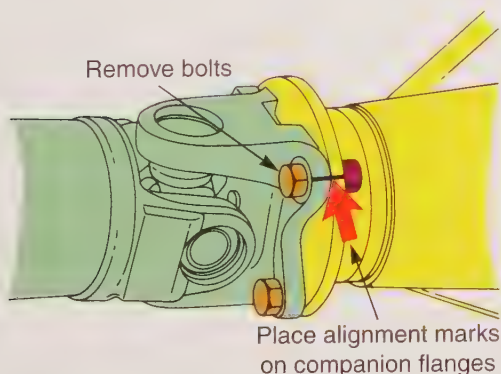


Figure 17-20. The drive shaft assembly must be removed before removing the rear axle assembly. Place match marks at the rear of the drive shaft and differential pinion yoke or flanges to help ensure proper reinstallation. (Chrysler)



Warning: Remember that the rear axle assembly is heavy and awkward. You should have another person help you hold the assembly as it is lowered with the jack. Be careful not to let the assembly fall during removal. Severe damage or injury could result.

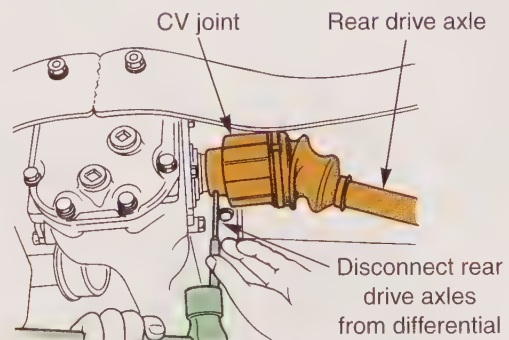
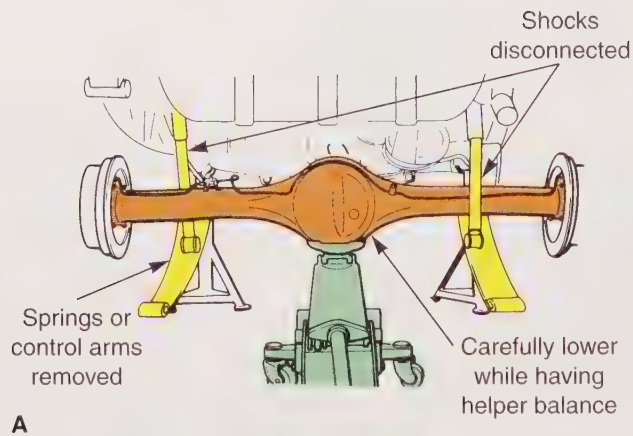
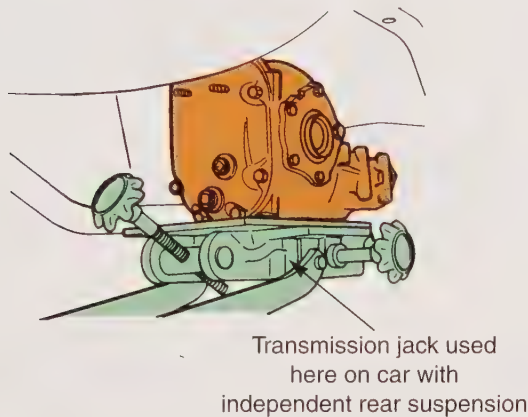


Figure 17-21. Remove the independently suspended drive axles before removing the rear axle housing. Removal methods vary. In the design shown, a roll pin is first removed from the inner stub axle with a punch and hammer. The next step would be to mark and remove the axle flange bolts and to remove the flange from the outer wheel hub assembly. Then, the inner stub axle would be pried from the differential carrier with a large screwdriver or other tool. (Chrysler, Subaru)



A



B

Figure 17-22. Carefully lower the rear axle assembly from under the vehicle. A—A rear axle assembly with a solid rear axle is shown being lowered from the vehicle with a floor jack. B—The rear axle housing from a vehicle with an independent rear suspension is shown being lowered with a transmission jack. (Subaru)

Differential Disassembly

Before beginning the disassembly, move the entire assembly to a bench or another place where it can be conveniently serviced. If possible, the assembly should be installed in a fixture, **Figure 17-23**, to make it easier to

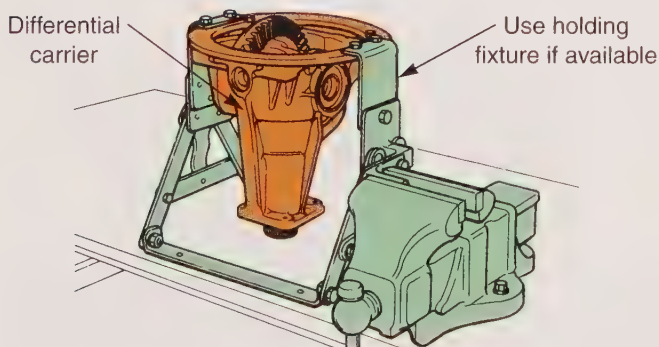


Figure 17-23. If a holding fixture is available, the differential should be bolted to the fixture for ease of servicing. If not available, the assembly should be securely placed on a workbench. (Chrysler)

work on. (Disregard this step for differentials with an integral carrier that is to be serviced on the vehicle.)

Remove drive axles if they have not been removed as of yet. Follow the procedure detailed earlier in the chapter for retainer-type axle or C-lock axle removal, as applicable. However, in the latter case, do not put the pinion shaft back after removing the C-locks.

Once the C-lock axles are out of the way, the spider gears and side gears can be removed. Turning one of the side gears with the pinion shaft removed will cause the spider gears to rotate out of the differential case. Both spider and side gears will have thrust washers between them and the case. These washers should be kept with the gears to avoid losing them and to simplify reassembly. For retainer-type axles, the removal of spider and side gears does not have to be done until after the differential case is removed from the differential carrier.

The procedure for removing the differential case from the carrier is shown in **Figure 17-24**. Mark the side bearing caps, if needed. Unbolt the bearing caps on the shim-type differential case (integral carrier) and remove the case. The shim-type case must be pried out of the carrier with a crowbar or other long metal bar. If threaded end caps are used instead of shims, remove them before removing the bearing caps and differential case. The bearing cups are positioned on the side bearings and are removed with the differential case. After the case is removed, remove any shims from the carrier.



Warning: If you are working under the vehicle, do not allow the differential case to fall on the floor when it comes loose.

Once the differential case is removed from the carrier, the drive pinion gear can be removed. The first step in drive pinion gear removal is to remove the large nut holding the pinion yoke/flange. The flange must be held to loosen and remove the nut. Once the nut is removed, the flange will slide out from the splines on the drive pinion gear shaft. If the flange is stuck, it can be loosened by lightly tapping the drive pinion gear with a brass or plastic hammer. The drive pinion gear can then be removed from the rear of the carrier. In some instances, the drive pinion gear is a snug fit with the front pinion bearing, and it must be lightly tapped through the bearing.

Pry the pinion seal out of the differential carrier with a large screwdriver. When the seal is removed, the front pinion bearing and any adjusting shims can be pulled out from the front of the carrier. Remove the rear pinion bearing from the pinion gear shaft using a press and adapters.

Usually, the side bearings are replaced when the rear axle assembly is overhauled. If you intend to reuse the bearings, do not remove them from the differential case, and take care not to switch the bearing cups. A bearing showing any signs of wear or damage should be replaced. **Figure 17-25** illustrates a method of removing the bearings using a gear puller.

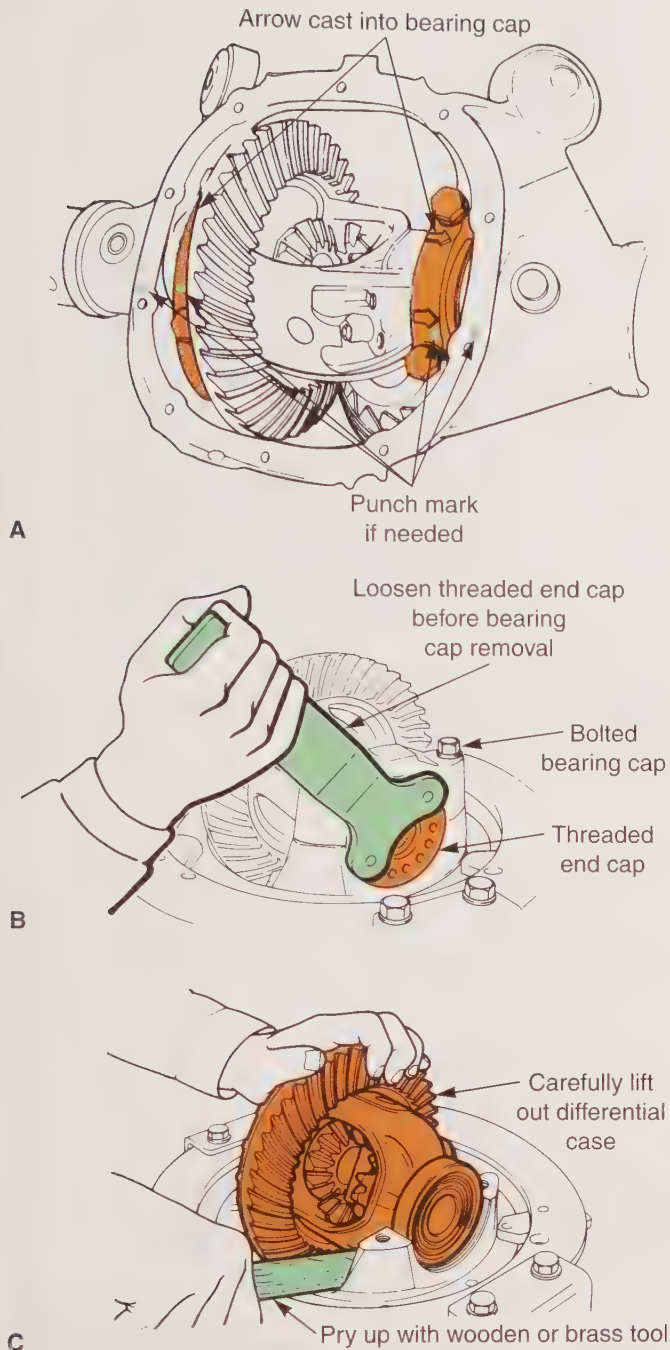


Figure 17-24. Steps to remove the differential case are shown. A—Mark the caps and carrier with a punch, if needed. Some bearing caps are already marked. If the case is the shim type, the bearing caps can then be unbolted and the case can be removed. B—If threaded end caps are used for adjustment, they should be removed before bearing cap removal. C—Once bolted bearing caps are removed, the case can be lifted from the differential carrier. (Ford, Chrysler)



Warning: Always wear eye protection when attempting to remove bearings, since metal chips are likely to fly around. Do not remove the bearings by cutting them with a torch, since the differential case is likely to be overheated and ruined.

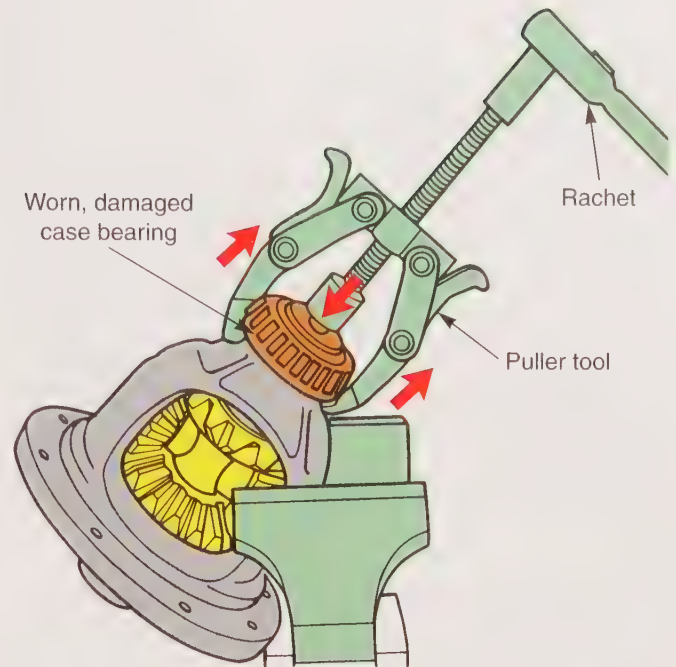


Figure 17-25. A puller such as this can be used to remove case bearings from the differential case. Bearings should be removed only if they are to be replaced. (Chrysler)

The ring gear should not be removed from the differential case unless it is defective or unless the drive pinion gear must be replaced. If the ring gear must be replaced, remove the bolts holding it to the case. After it is unbolted, it can be lightly tapped loose with a brass hammer or plastic mallet, **Figure 17-26**.



Note: The ring and pinion are a matched set. They should always be replaced as a set. Mixing new and used gears will result in a noisy gearset that will fail quickly.

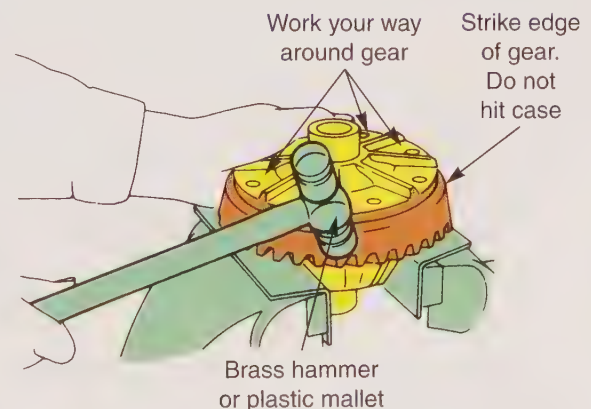


Figure 17-26. The ring gear should be removed from the case only if it is to be replaced. After the bolts are removed, the ring gear can be removed by tapping it lightly with a hammer. (Nissan)

If spider and side gears have not yet been removed from the differential case, remove them now. First, as previously stated, remove the pinion shaft lock bolt or pin, and drive or slide the pinion shaft from the case, **Figure 17-27**. Turn one of the side gears until the spider gears rotate out of the case. Then, remove the side gears and thrust washers.

If disassembling a limited-slip differential assembly, the clutches can be removed by removing the bolts holding the case together, since most limited-slip differential cases are made in two pieces. After the case is apart, the components can be lifted out. Carefully note the position of all limited-slip components as you disassemble the case.

Figure 17-28 illustrates the parts of a limited-slip differential case assembly. Standard differentials are similar, but they do not contain the limited-slip clutches. Every part should be inspected for wear and damage.

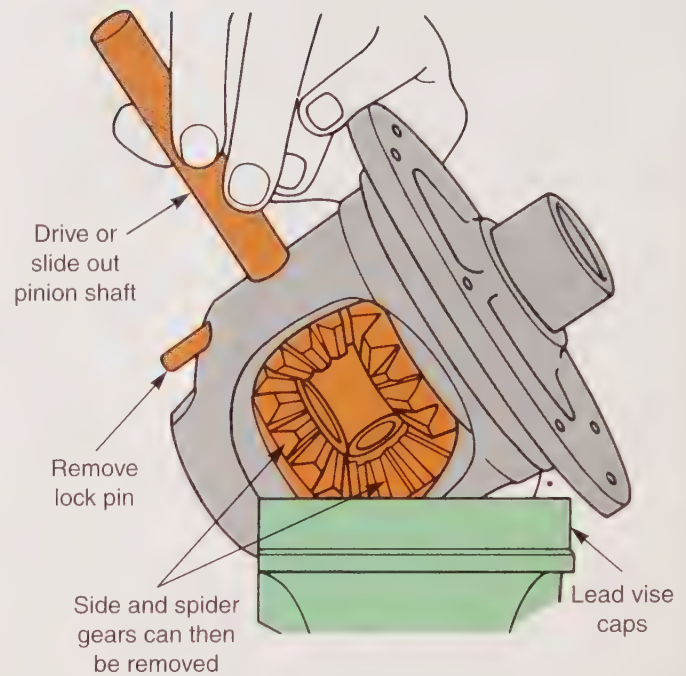


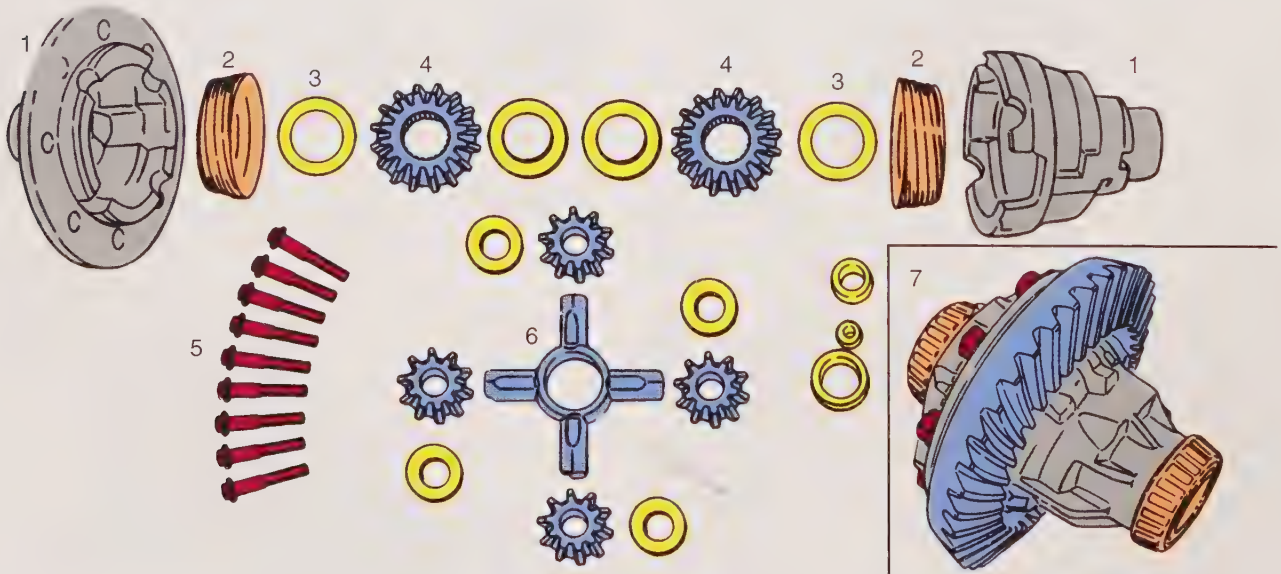
Figure 17-27. Note the removal of the lock pin and pinion shaft to gain access to the spider and side gears in the differential case. (Chrysler)

Differential Assembly Parts Inspection

When checking the differential components, pay particular attention to the bearings and bearing outer races, since they are a common source of rear end noise. Also, check all of the gears for wear and scoring. Check for pitting on gear and bearing surfaces, which is often caused by water in the oil. Make sure the side gear and axle splines are not worn. Check the limited-slip differential clutches for wear. This is usually noticed as shiny contact surfaces or extreme smoothness. Once the differential has been checked, obtain new gaskets and seals. Obtain other new parts as needed.

Differential Reassembly

The first step in differential reassembly is replacing the pinion outer races, or bearing cups, if needed. The old bearing cups can be driven out of the differential carrier



1. Inspect case for wear and cracks or other damage.
2. Check cone friction surfaces for wear.
3. Measure thrust washer wear.
4. Inspect side gear teeth and splines.
5. Make sure none of the bolt threads are damaged.
6. Check spider gears and other parts for wear.
7. Inspect before, after, and during repairs.

Figure 17-28. Exploded view of a limited-slip differential shows the parts that must be cleaned, inspected, and, if necessary, replaced. Standard differential case assemblies are similar. (General Motors)

with a hammer and drift, as shown in **Figure 17-29A**. Be careful not to gouge the housing surfaces when removing the bearing cups.

Figure 17-29B shows the correct method of installing new bearing cups. If a special tool is not available, the cups must be very carefully driven into place. The bearings are closely machined, and the slightest mark on the bearing cup will ruin it.

After the bearing cups are in place, install the front pinion bearing and pinion seal in the carrier. The bearing should be lightly lubricated before installation. The pinion seal should be installed with a special seal installation tool, as shown in **Figure 17-30**. Do not forget to install any bearing spacers, or shims, that may have been present between the bearing and the carrier.

Press the rear pinion bearing on the drive pinion gear shaft. Use a new bearing and new drive pinion gear if needed. If a new pinion gear is needed, you must also replace the ring gear. **Figure 17-31** shows the markings of a typical ring and pinion gaset. Always check the markings of replacement gaset to ensure the proper ring and pinion are being installed. The number of teeth on each gear should match the number of teeth on each of the old gears, unless you are intentionally modifying the rear axle ratio.

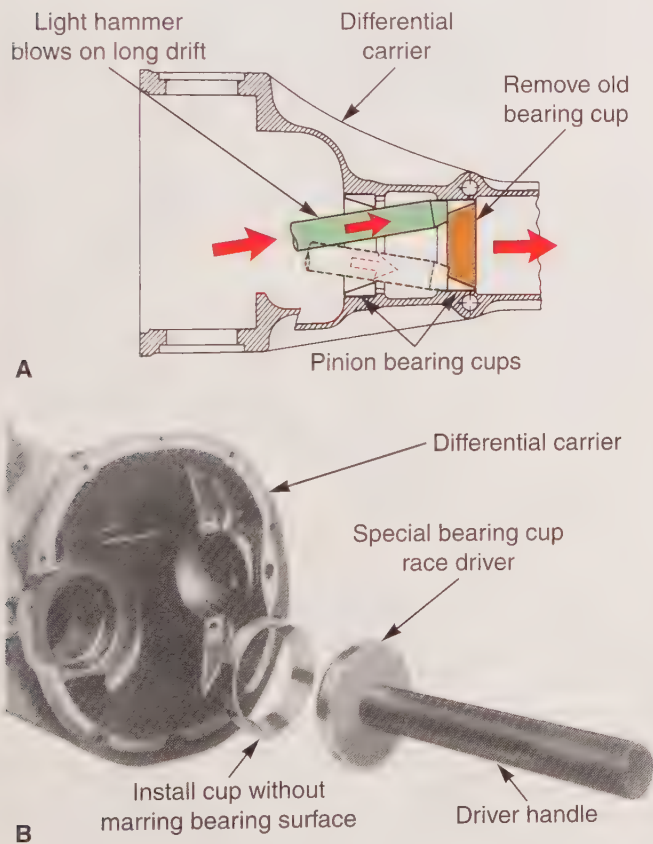


Figure 17-29. Study bearing cup replacement. **A**—Bearing cups can be removed with a hammer and a long punch or drift. Do not gouge the differential carrier with tools during removal. **B**—A driver should be used to install replacement cups. Do not damage cup surfaces. (Subaru, General Motors)

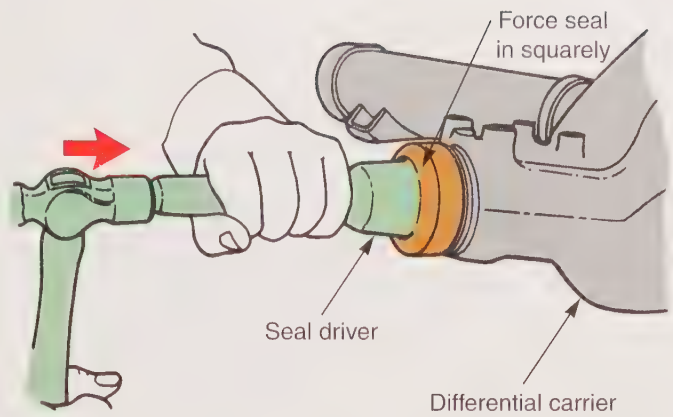


Figure 17-30. A new pinion seal should be installed with a seal driver and a hammer. The seal should be completely seated against the housing. (Chrysler)

There is usually a steel shim between the drive pinion gear and the rear pinion bearing. This shim adjusts the pinion gear depth in the differential carrier. Pinion gear depth has a critical effect on the contact pattern between the pinion and ring gears. The shim is matched to the carrier. You should reinstall the same one, unless the carrier has been changed. If a new carrier is used, a special procedure must be followed to select the proper replacement shim.

To install the rear pinion bearing, use a hydraulic press. The bearing must be completely bottomed on the drive pinion gear and shim. Lightly lubricate the bearing before installation.

To install the drive pinion gear in the differential carrier, place a new collapsible spacer or solid spacer, as required,

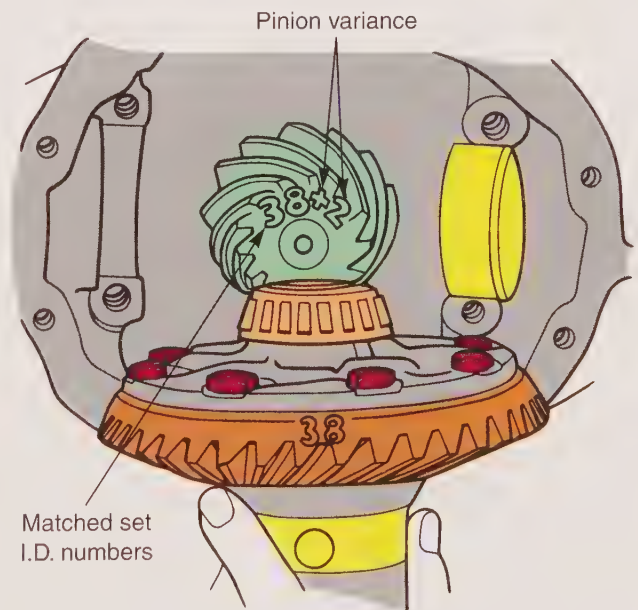


Figure 17-31. Ring and drive pinion gears must always be installed in matched sets. Markings on replacement sets should be checked to ensure they have been matched at the factory. (Chrysler)

ahead of, or on the forward side of, the rear pinion bearing. A collapsible spacer places the proper preload on the pinion bearings, and a new one should always be used. A solid spacer can be reused.

Install the drive pinion gear in the differential carrier by sliding the drive pinion gear shaft through the front pinion bearing. Then, install the pinion yoke and a new nut. Tighten the nut until the drive pinion gear has no back-and-forth play. See **Figure 17-32A**.

As the pinion nut is tightened, it will slightly compress a collapsible spacer or contact a solid spacer and preload the bearings. See **Figure 17-32B**. The final bearing preload can normally be measured with an inch pound torque wrench, **Figure 17-32C**. Typical preload readings are 4 in lb–11 in lb (0.5 N•m–1.3 N•m). Always check the service manual for the exact reading. You must be very careful to reach the exact preload figure without going beyond it. If you overtighten the pinion nut, the drive pinion gear will have to be removed, and a new collapsible spacer will have to be installed.

With the drive pinion gear assembly in place, you are ready to assemble and install the differential case assembly. Before permanently installing the spider and side gears, check the clearances, as recommended by the manufacturer. Typically, this will involve checking the clearance between the splines of the side gears and the axles. This is determined by measuring the side gear-to-axle play with a dial indicator, **Figure 17-33A**. It will also involve checking the spider gear-to-side gear backlash. This is measured by checking the play between the two gears, **Figure 17-33B**. The thrust washers should be in place when doing this test.

After checking clearances, the spider and side gears can be installed permanently. Lubricate the differential case components with rear axle assembly lubricant, including the thrust washers, gears, and pinion shaft. Then, reinstall the parts, starting with the side gears. After the side gears are in place, the spider gears can be walked into position as shown in **Figure 17-34**. Once these are in place, install the pinion shaft and lock bolt or pin.



Note: The internal parts of a differential case assembly used on C-lock axles cannot be reinstalled in the case until the case is reinstalled in the differential carrier.

If the differential is the limited-slip type, reassembly is relatively easy. First, lubricate all parts, including the clutch friction discs and steel plates, **Figure 17-35**. Assemble the parts in one half of the differential case. Then, reassemble the two halves of the case. See **Figure 17-36**. The clutches can be bench checked with a torque wrench, **Figure 17-37**. The readings should be the same as they were for the differential while installed in the vehicle (30 ft lb, or 41 N•m minimum).

If a new ring gear is being used, install it now on the differential case. The ring gear may be keyed or the bolt pattern may be arranged so that there is only one way to install the

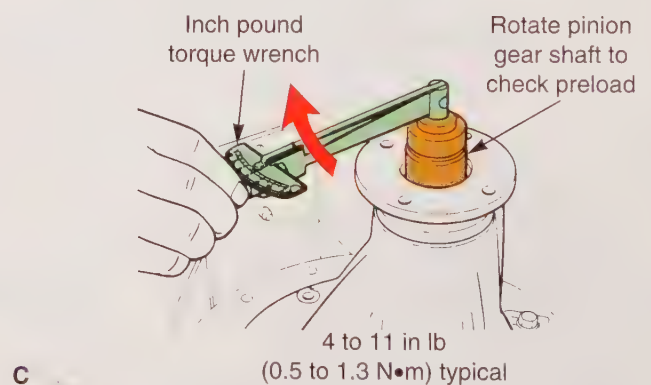
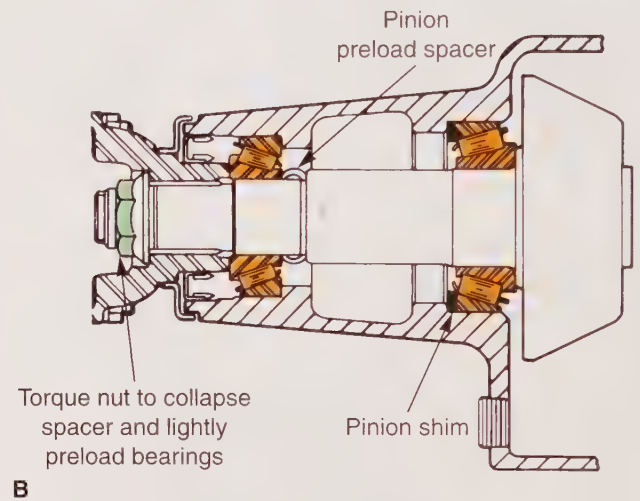
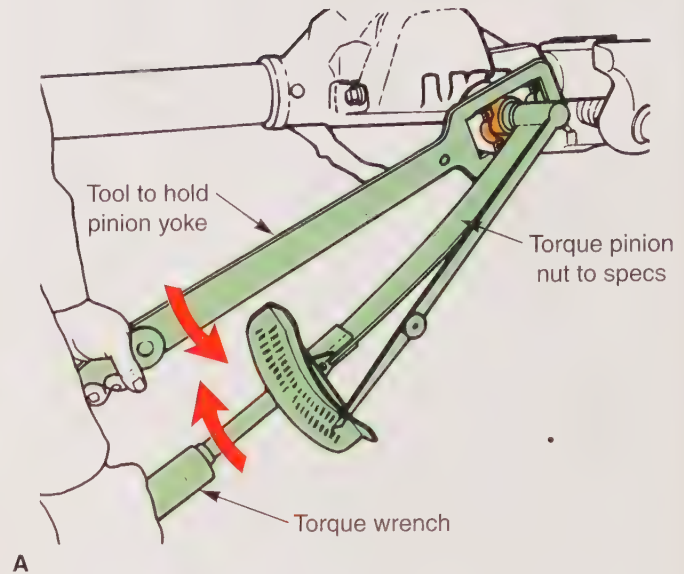
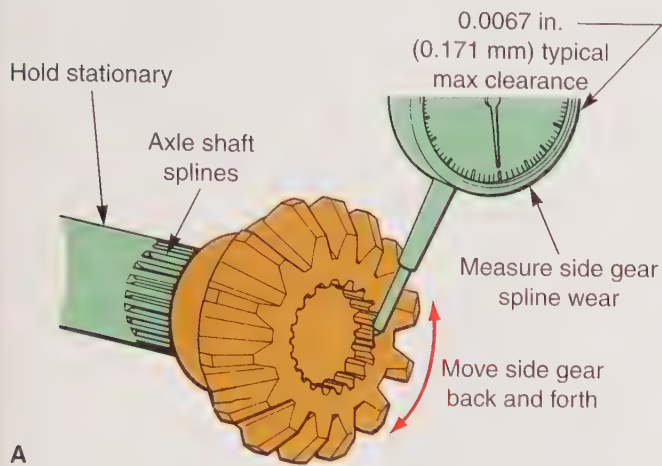
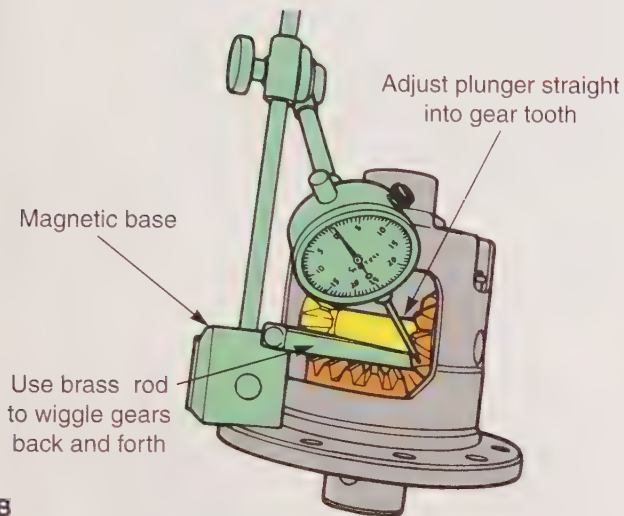


Figure 17-32. Note important details concerning the installation of the drive pinion gear. A—Tighten the large nut on the pinion gear shaft to collapse the spacer and preload the bearings. B—The drive pinion gear assembly will look like this when properly assembled. A collapsible spacer preloads the pinion bearings. C—Proper preload will cause a slight drag on the drive pinion gear shaft when it is rotated. The drag is measured in inch pounds or Newton-meters. (Chrysler)



A



B

Figure 17-33. Side gears and spider gears must be checked for wear. Consult a service manual for proper clearance specifications. Not all manufacturers provide specifications for these measurements. A—Side gear-to-axle clearance can be measured with a dial indicator to check for looseness between the two. B—Temporarily assemble thrust washers and differential gears to measure spider gear-to-side gear backlash. (Chrysler, General Motors)

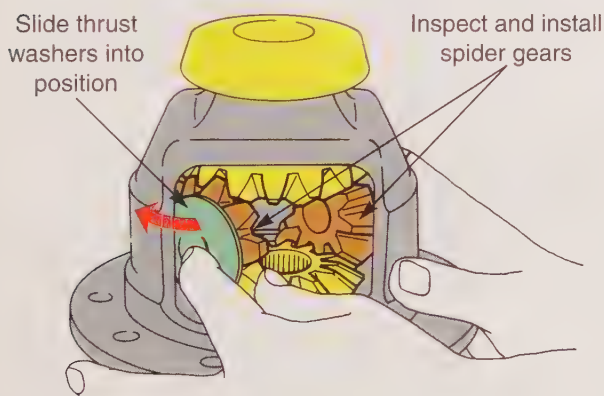


Figure 17-34. Spider gears and thrust washers must be installed into the differential case as a unit. Spider gears should be placed on the side gears and then rotated into the case. Do not allow thrust washers to fall out of position. (Nissan)

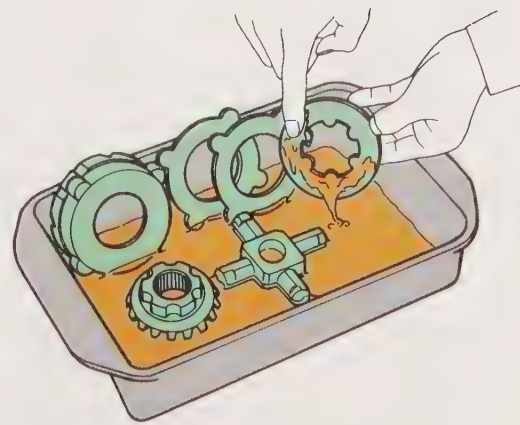
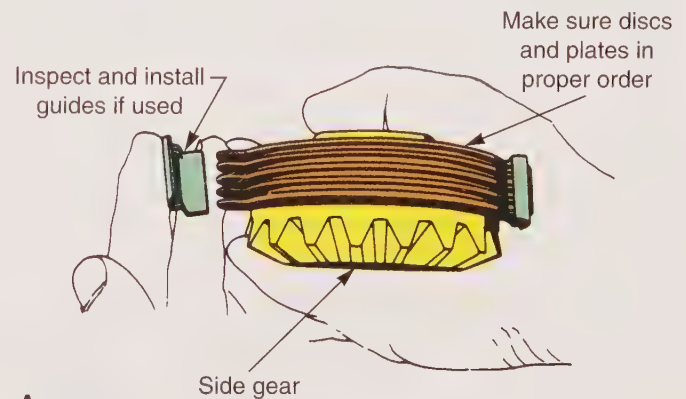
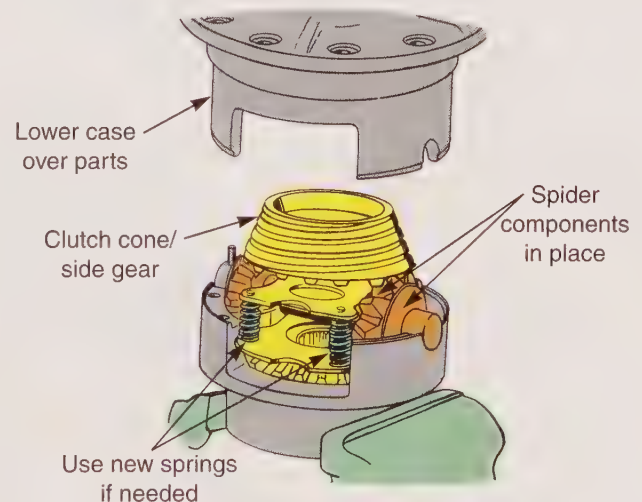


Figure 17-35. Lubricate the differential case assembly parts, including limited-slip clutches. Submerging the parts in a pan of lubricant is an ideal way to lubricate them. Be sure to use recommended limited-slip differential gear oil, where applicable. (Nissan)



A



B

Figure 17-36. This shows the differential case assembly of a limited-slip differential. A—Multiple-disc clutches should be stacked in the case, alternating friction discs and steel plates. B—Cone clutches must be engaged with driving lugs on side gears. Place the other half of the case over the assembled parts. (General Motors)

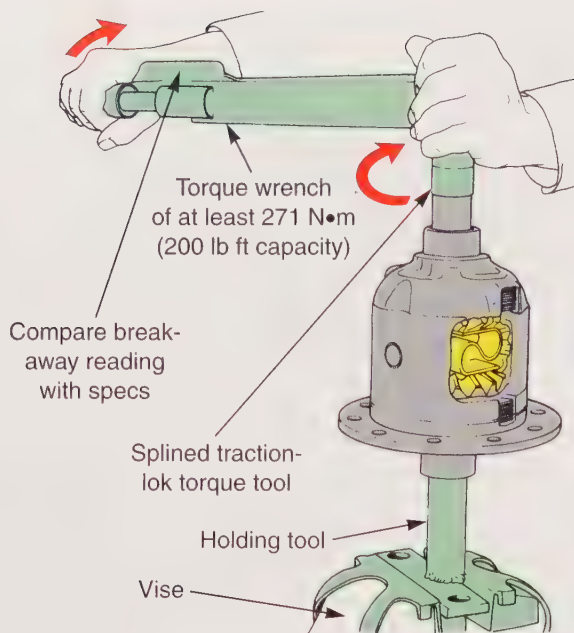


Figure 17-37. After reassembly, a limited-slip differential can be checked with a torque wrench. The procedure is the same as that performed with the rear end assembled. It may be necessary to fabricate a tool to hold and turn the side gears. (Ford)

ring gear on the case. The gear should be placed on the case and lightly tapped into place with a soft hammer or a block of wood. Be very careful not to chip or nick the gear teeth.

Install and tighten the attaching bolts in a crisscross pattern. This is done so that one side is not tightened before the other side is bottomed out. Torque the bolts to the specified torque values.

Note that if the differential is the type used with independent rear suspension, as shown in **Figure 17-38**, you will need to select the proper number of shims to preload the side bearings. The original number of shims will usually work. See the manufacturer's service manual for more information on adjusting.

If new side bearings are needed, install them now. Position each bearing cone on the hub of the differential case. Use an arbor press in conjunction with a bearing driver to press the bearings into position. See **Figure 17-39**.

Lightly lubricate the side bearings. The differential case can now be lowered into the differential carrier, **Figure 17-40**. The bearing cups and adjusting shims, if used, should be installed with the case. Since the adjusting shims are tightly fitted into the case to preload the bearings, they may need to be tapped into place with a soft hammer. Differential carrier spreading tools are available to slightly expand the carrier for easier shim installation.

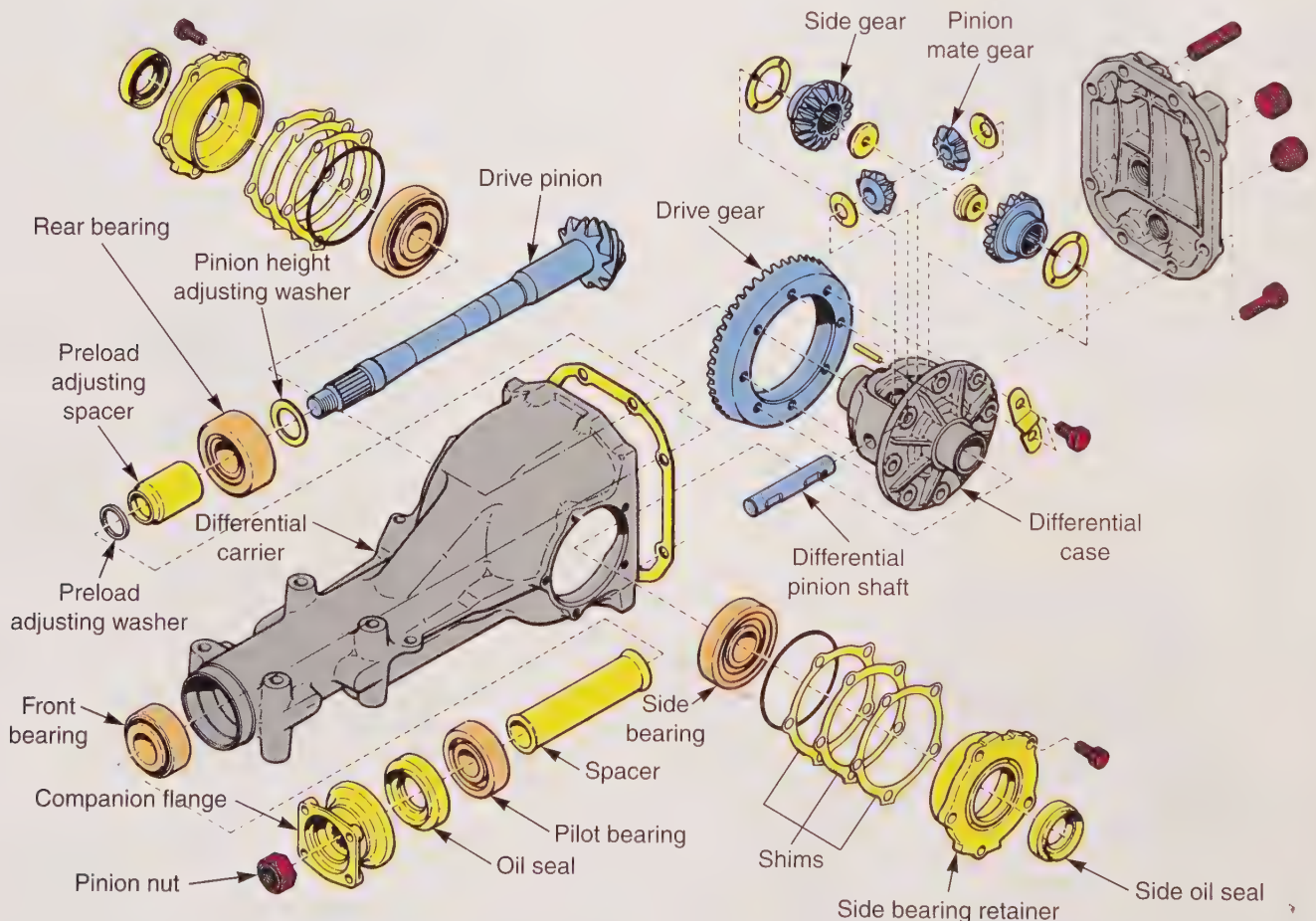


Figure 17-38. Exploded view of a rear axle assembly used with an independent rear suspension shows the shims that are used to adjust side bearing preloads. Other parts resemble those used on standard rear axle assemblies. (Subaru)

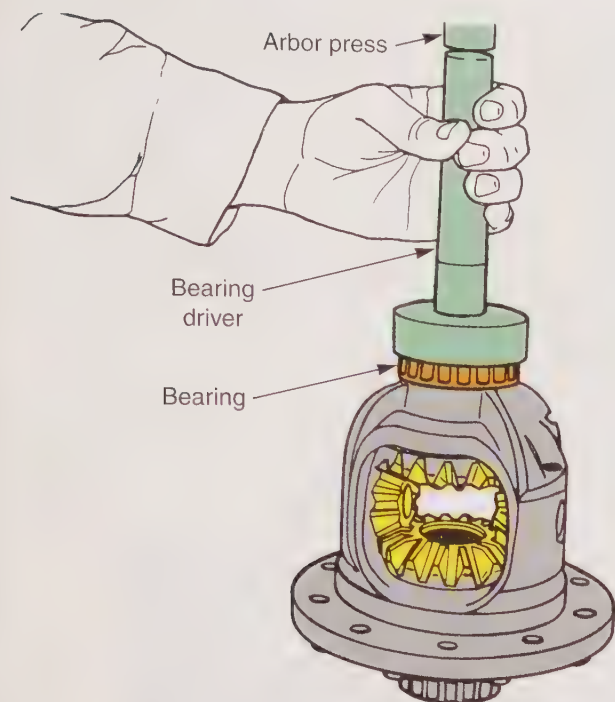


Figure 17-39. This shows the installation of a side bearing using an arbor press. Note that the bearing cone taper is away from the differential case. Also, never exert pressure against the bearing cage. Bearing damage may result. (Chrysler)

It may be necessary to add or subtract shims to obtain the proper bearing preload. This procedure is discussed in the next section. After the bearing cups and shims are in place, install the bearing caps and torque the retaining bolts. After the bolts are tight, rotate the differential case to ensure the bearings are not binding.

Differential Assembly Adjustments

There are several adjustments that must be made when assembling a differential. Bearing preloads, ring gear

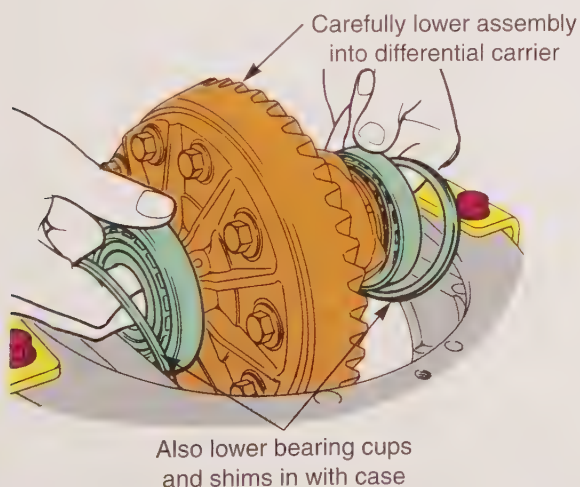


Figure 17-40. Carefully lower the differential case assembly, bearing cups, and shims into the differential carrier as a unit. It may be necessary to use a special carrier spreading tool to allow shims to slip into place. (Chrysler)

backlash, ring gear runout, and ring gear contact patterns are extremely critical. These must be checked and, if necessary, adjusted.

Side bearing preload

Side bearing preload is the amount of force pushing the side bearings of the differential case together. Side bearing preload is critical. If it is too low, bearings are too loose. Differential case movement and ring and pinion gear noise can result. If preload is too high, the side bearings are too tight, and bearing overheating and failure can result.

When end caps are used, the caps are usually tightened until all the play is out of the bearings. Then, each cap is tightened a certain amount to preload the bearings. Lock plates are installed to prevent the end caps from backing off, **Figure 17-41**.

When shims are used, you may need to use a feeler gauge to check the clearances between the side bearings and differential case. See **Figure 17-42**. The method shown allows you to calculate the correct shim thickness to preload the side bearings properly. Refer to a shop manual for more specific procedures.

Ring gear backlash

After the differential case is installed, use a dial indicator to check **ring gear backlash**—the clearance, or play, between the ring and pinion gears. To check ring gear backlash, place the plunger of a dial indicator on a ring gear tooth, as shown in **Figure 17-43**. Lock the drive pinion gear in place and rock the ring gear back and forth. The movement registered by the dial indicator is the backlash. A typical ring gear backlash setting is about 0.005"–0.012" (0.13 mm–0.31 mm).

Ring gear backlash can be changed. For a differential case assembly with adjusting nuts (end caps), this is accomplished by turning the nuts, as shown in **Figure 17-44A**. For an assembly adjusted with shims, proper-sized replacement shims must be used to adjust the backlash. See **Figure 17-44B**. Adjustments must be made to each side of the case so that they offset each other to maintain the proper bearing preload. Ring gear backlash may need to be readjusted after the gear tooth pattern is checked, as will be explained shortly.

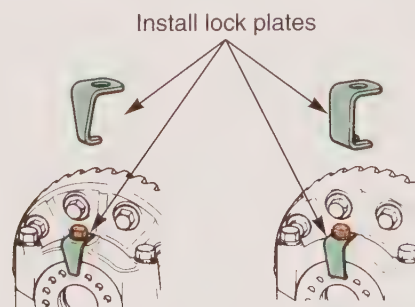
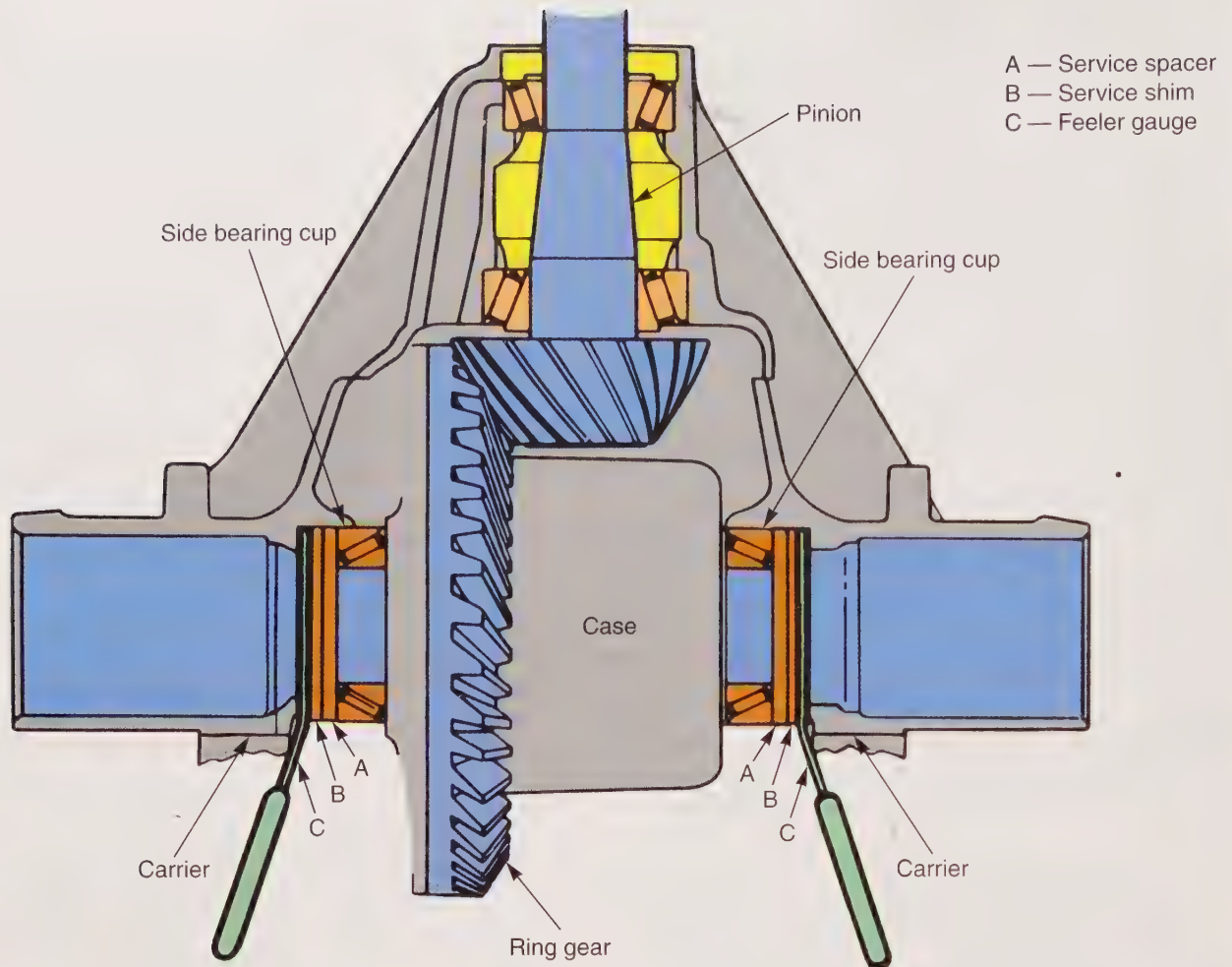


Figure 17-41. Install lock plates to keep the end caps from backing off and coming out of adjustment. (Chrysler)



Example

Ring Gear Side		Opposite Side	
Combined total of:		Combined total of:	
.250"	Service spacer (A)	Service spacer (A)	.265"
	Service shim (B)	Service shim (B)	
	Feeler gauge (C)	Feeler gauge (C)	
- .010"	To maintain proper backlash (.005" - .008"), ring gear is moved away from pinion by subtracting .010" shims from ring gear side and adding .010" shims to other side.		+ .010"
.240"			.275"
+ .004"	To obtain proper preload on side bearings, add .004" shims to each side.		+ .004"
.244"	Shim dimension required for ring gear side	Shim dimension required for opposite side	.279"

Figure 17-42. This shows the procedure for adjusting bearing preload and, also, ring gear backlash on a shim-type differential case. To maintain proper preload, always keep the total shim thickness the same. For example, if you must subtract 0.01" from one side, you must add 0.01" to the other side. (General Motors)

Ring gear runout

Ring gear runout—the amount of wobble when the ring gear is rotated—should also be checked after the differential case is installed. Check ring gear runout by placing the dial indicator on the back side of the ring gear, **Figure 17-45**. Rotate the ring gear. The dial indicator movement is the runout. Runout should not exceed about 0.005" (0.13 mm).

Ring gear runout can usually be corrected only by replacing the ring gear and differential case. However, once in a while, runout can be corrected by changing the position of the ring gear on the differential case. Also, if a new ring gear was installed on the case, some dirt or metal shavings may have been caught between the gear and the case. Removing and cleaning both surfaces may eliminate excessive runout.

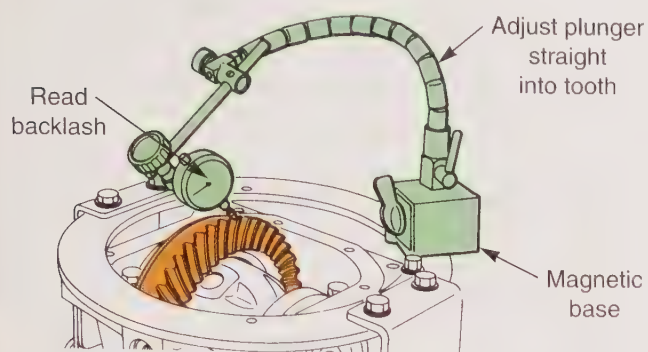


Figure 17-43. Ring gear backlash can be checked with a dial indicator. Check backlash with the drive pinion gear locked in place. Backlash should be within the manufacturer's range. (Chrysler)

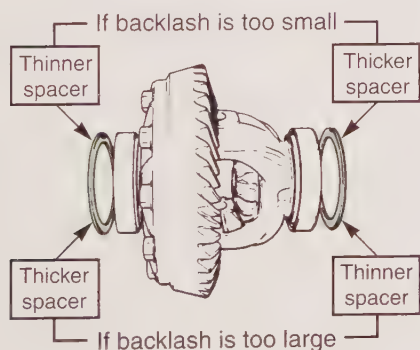
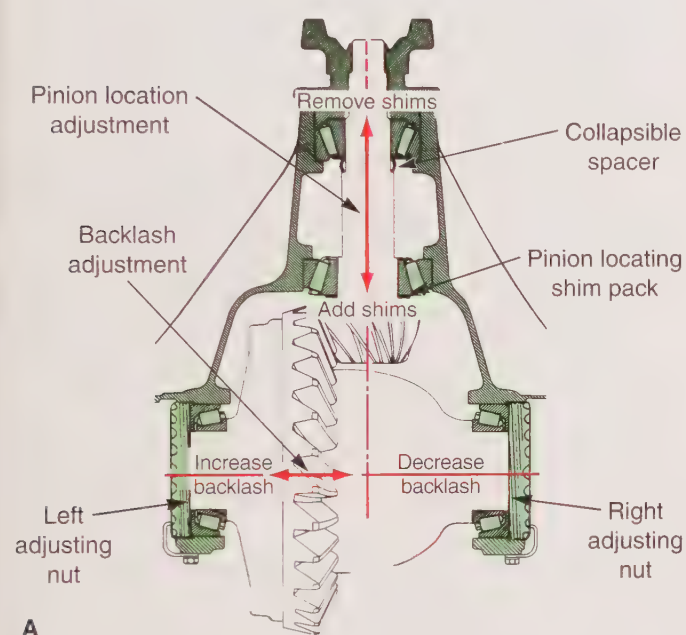


Figure 17-44. Ring gear backlash can be changed by turning the adjusting nuts or adding thicker or thinner shims. A—Turn the left adjusting nut (in illustration) inward to decrease backlash. Turn the nut outward to increase backlash. Be sure to maintain proper bearing preload. B—Add the thicker shim to the left side and the thinner shim to the right side to decrease backlash. Do the opposite to increase backlash. (Ford, Chrysler)

Ring gear contact pattern

Once the ring gear backlash and runout are checked, check the ring gear contact pattern. The tooth pattern between the ring and drive pinion gears is critical to quiet operation and long gear life. Refer to **Figure 17-46** for the contact pattern checking procedure.

Begin the procedure by coating the ring gear teeth with white grease. **Machine blue**, also called **Prussian blue**, can be used in its place. Machine blue is a deep blue dye mixed in a grease-like substance. Use a small stiff bristle brush to apply a light even coat of the white grease or machine blue.

Use the drive pinion gear to rotate the ring gear through one complete revolution in the normal forward direction and one revolution in reverse. Apply a load to the back side of the ring gear. This will create a contact pattern on both sides of the ring gear teeth. Inspect the pattern on the entire ring gear. If the pattern is normal—that is, if the contact area is in the middle of both sides—no further adjustments are necessary. Otherwise, the positions of the ring gear and drive pinion gear must be adjusted.

If incorrect contact is caused by too much or too little backlash, adjust the side bearing shims or end caps, as previously described. Be sure to maintain the proper bearing preload. If the drive pinion gear shim is incorrect, the unit will require disassembly to remove the rear pinion bearing and change the pinion shim. Always recheck the contact pattern after making adjustments.

When finished, wipe off the excess grease or machine blue. It is not necessary to remove all of it, since it will mix with the rear end lubricant. The differential assembly is now ready for reinstallation.

Differential Assembly Installation

Following are some general procedures detailing how to install a differential assembly safely and properly. The exact procedure for installation varies according to the type of differential, but basically it is the reverse of removal. Always refer to the manufacturer's service manual for specific procedures.

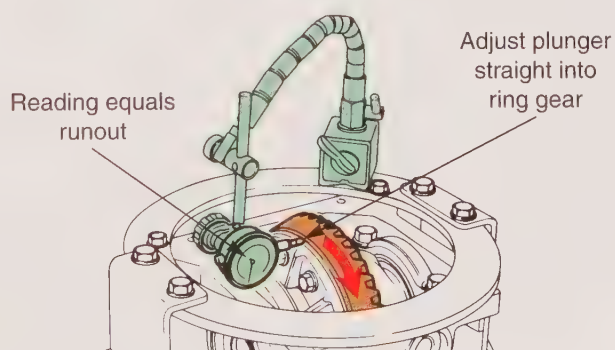


Figure 17-45. Measure the ring gear runout by placing a dial indicator against the back side of the ring gear and rotating the ring gear. (Chrysler)

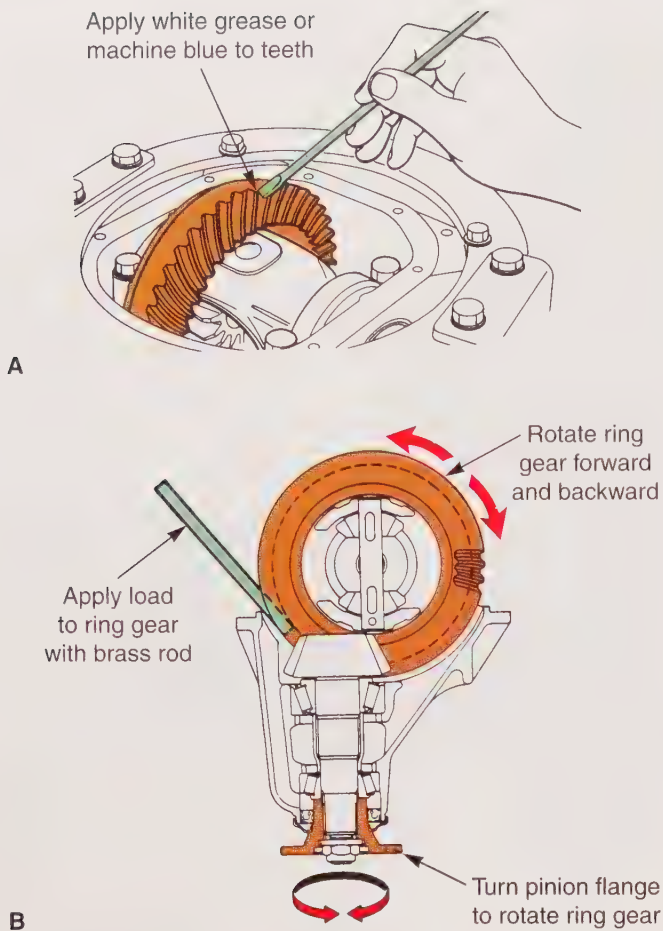


Figure 17-46. This shows the procedure for checking the ring gear contact pattern. A—Apply white grease or machine blue to teeth. B—Rotate the ring gear by turning the pinion yoke/flange. Apply the load to the back side of the ring gear at same time. Turn the ring gear through one complete revolution forward and one complete revolution backward. Then check the contact pattern. (Chrysler)

Removable carrier

The following procedure details the proper way to install a differential assembly from a rear axle assembly having a removable carrier.

1. Place a new gasket over the studs on the rear axle housing, where the differential carrier mates with the rest of the housing. Make sure that no old gasket is stuck on either of the mating surfaces.
2. With the help of an assistant, raise the carrier into position and slide it over the studs. Place a jack stand under the carrier to support it.
3. Install the nuts and tighten them in an even pattern to prevent binding. Torque the nuts to the proper specifications.
4. Install the drive axles in the rear axle housing. (Refer to the drive axle installation section occurring earlier in the chapter.)
5. Install the brake drums and wheels.
6. Install the drive shaft assembly, aligning match marks made during disassembly.
7. Install any hardware that was attached to the carrier.

8. Lower the vehicle. Check the brakes. Test-drive the vehicle to ensure proper operation.

Integral carrier

Integral carriers do not generally need to be reinstalled unless the entire rear axle assembly was removed to service the assembly on a workbench. The following procedure details the proper way to install a rear axle assembly of a vehicle with either solid-axle rear suspension or independent rear suspension.

1. Install the solid drive axles in the rear axle housing. (Refer to the drive axle installation section presented earlier in the chapter.)
2. Check the differential cover for damage or warping (if not already installed). Scrape off any old gasket material from the cover or its mating surface on the rear axle housing. Install a new gasket and use a nonhardening gasket sealer. Note that some manufacturers recommend using form-in-place gaskets. The bead of this type of gasket should be laid evenly and should completely encircle all bolt holes.
3. Tighten the differential cover bolts in a crisscross pattern. Torque the bolts to manufacturer's specification.
4. Place the rear axle assembly under the vehicle and raise it into position. Have a helper assist you and use a floor jack or transmission jack to lift the assembly. Support the rear axle housing with a jack stand. Then, install all rear axle housing attaching hardware.
5. Install independently suspended drive axles, if necessary.
6. Reconnect miscellaneous items such as brake lines, parking brake cables, exhaust pipes, and suspension components.
7. Install the drive shaft assembly, aligning match marks made during disassembly.
8. Install the brake drums and wheels.



Warning: If the brake lines were removed, bleed the brakes before road testing the vehicle.

9. Add the proper type of rear axle assembly lubricant.
10. Lower the vehicle. Check the brakes. Test-drive the vehicle to ensure proper operation.

Note that if properly assembled, most rear axle assemblies will at least allow the vehicle to be driven. The main concern will be noise. To check for noises, find a quiet road with smooth pavement. If the rear end is quiet at about 35–45 mph, it is working properly and everything is in order.

To check the limited-slip clutches, make several slow turns in a quiet area, such as an empty parking lot. If the vehicle turns smoothly, without shuddering or noises, the clutches are working properly. Sometimes, the limited-slip clutches will make noise or work erratically for the first few miles, until the clutch surfaces have time to wear in.

Summary

The technician should always begin rear axle assembly troubleshooting by checking the oil level. Add oil as needed. If this does not solve the problem, proceed to check other possible causes. Most rear axle assembly problems fall into three main areas: noises, vibrations, or leaks.

Rear axle assembly noises include clunking, whining, and rumbling. Noises can be caused by worn or misadjusted gears, defective bearings, or excessive clearance between gears. Make sure the noise is actually coming from the rear axle assembly, since other components can make similar sounding noises.

Vibrations are usually caused by bent axles or axle flanges. The source of the vibrations should be carefully determined, since vibration can be caused by many other parts of the vehicle.

Oil leaks can be caused by seal or gasket failure, overfilling or water contamination, loose bolts, or cracked housings. They can usually be spotted by oil drips and stains from the defective part.

Problems in limited-slip differentials usually show up on turns. Defective clutches or the wrong oil will cause the rear axle assembly to shudder or make noises when turning corners. Limited-slip differential repair usually involves disassembling the rear axle assembly.

Solid axles are removed by two different methods, depending on whether retainer-type or C-lock axles are used. C-lock axles require partial disassembly of the differential, while retainer type axles do not.

To remove an independently suspended drive axle, remove the fasteners that hold the drive axle flange to the carrier and to the wheel hubs. Once the flanges are removed, the drive axle can be removed from the vehicle.

Axle bearing removal procedures are also different. Bearings for C-lock axles must be removed from the housing, while those for retainer-type axles must be removed from the axle. Axle studs can be replaced on or off the vehicle.

Axle seals should be replaced when they begin leaking or when performing any other drive axle service procedure. If a seal is leaking badly, the brake linings should also be checked. The old seal can be pried out with a special tool or screwdriver. The new seal should be installed with a special driver so it is flush against the housing.

Before removing the rear axle assembly, it should be checked to ensure an internal problem exists. The vehicle should be operated on a lift to determine the exact problem. Limited-slip differential clutches can be checked with a torque wrench.

The methods of removing the rear axle assembly vary according to type. In many cases, the integral carrier design can be serviced from under the vehicle. In other cases, it is easier to work on the rear axle assembly on a bench.

Rear axle assembly disassembly starts in the differential case area. The side and spider gears can be removed if

rear axle assembly has C-lock axles. Then, the side bearing caps are removed, and the case is lifted or pried from the case. Once the case is removed, the drive pinion gear can be removed by removing the nut holding the pinion flange to the pinion gear. The pinion gear and bearings can then be removed from the case.

All parts should be inspected for wear and damage. New gaskets and seals should be obtained. Bearing cups should be installed very carefully. You should reinstall the same shim, unless the carrier has been changed. If a new carrier is used, a special procedure must be followed to select the proper replacement shim. The drive pinion gear can then be installed, and the flange nut can be tightened.

The side and spider gears and limited-slip components, if applicable, can be reinstalled in the differential case. The case is then installed in the differential carrier, the bearing caps are tightened, and the backlash and run-out are checked. Adjustment varies according to whether the side bearings are preloaded with end caps or shims. Then, the ring gear contact pattern is checked and adjusted as needed. The ring and drive pinion gears may both require adjustment.

After the rear axle is reassembled and adjusted, it can be reinstalled in the vehicle. Installation is the reverse of removal for both solid drive axle and independently suspended drive axle. For the solid drive axle, do not forget to add the proper lubricant to the differential and to bleed the brakes if the brake lines were disconnected.

The vehicle should be road tested for proper operation. Most problems after overhaul will involve abnormal noises. Some limited-slip differential components may require some run-in to operate properly.

Review Questions—Chapter 17

Answer the following questions using the information provided in this chapter.

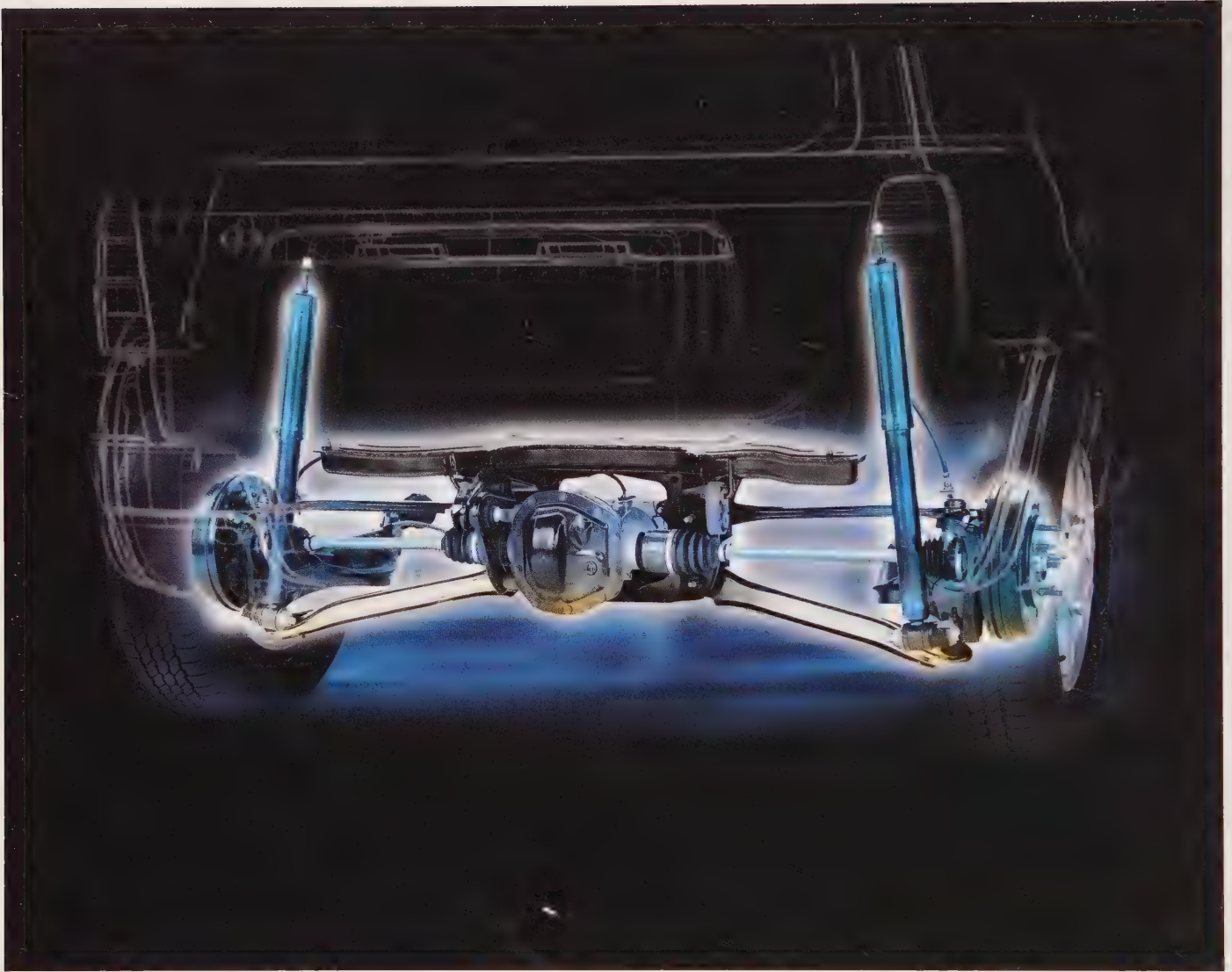
1. What should you check first with most rear axle assembly problems?
2. If whining noises occur when the vehicle is first accelerated, but not when coasting, the ____ pinion bearing may be defective.
3. If whining noises occur when the vehicle is coasting, but not when accelerating, the problem is most likely the ____ pinion bearing.
4. Rumbling or roaring noises almost always indicate worn or damaged ____.
5. What might an oil leak at the rear axle housing indicate?
6. Problems related to the limited-slip feature usually occur when the vehicle is ____ on slippery surfaces or turning a corner.
 - (A) skidding
 - (B) coasting
 - (C) braking
 - (D) accelerating

7. In order to remove a(n) _____ axle, the differential cover must be removed.
8. A leaking axle seal can make a car's _____ unsafe.
9. If a seal is not precoated, a light coat of _____ sealer should be placed around the outside diameter.
10. Each of the following is an adjustment that must be made when assembling a differential *except*:
 - (A) side bearing preload.
 - (B) ring gear backlash.
 - (C) axle endplay.
 - (D) ring gear runout.
11. A(n) _____ spacer can be reused.
12. Side bearing preload is adjusted by means of _____.
 - (A) shims
 - (B) adjustable end caps
 - (C) collapsible spacers
 - (D) Both A and B.
13. Ring gear _____ is the clearance, or play, between ring and pinion gears.
14. Ring gear _____ is the amount of wobble in the ring gear as it rotates.
15. To adjust a differential assembly where tooth contact is localized on the crests of the drive side and coast side tooth faces, move the _____.
 - (A) ring gear away from the drive pinion gear using a thinner side bearing shim
 - (B) ring gear closer to the drive pinion gear using a thicker side bearing shim
 - (C) drive pinion gear closer to the ring gear using a thicker pinion gear shim
 - (D) the drive pinion gear away from the ring gear using a thinner pinion gear shim
3. A rear-wheel drive vehicle has a severe lubricant leak from the center of the rear axle assembly. Technician A says that the cause could be a leaking pinion seal. Technician B says that the cause could be loose bolts on the differential cover. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
4. Technician A says that automatic transmission fluid can be used to refill a limited-slip differential. Technician B says that standard 80- to 90-weight gear oil can be used to refill a limited-slip differential. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
5. Technician A says that the drive axle can be loosened using a slide hammer after the retainers are removed. Technician B says that the differential must be partially disassembled to remove a retainer-type drive axle. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
6. Which of the following parts need not be removed to remove a C-lock from a drive axle?
 - (A) Pinion shaft lock bolt.
 - (B) Pinion shaft.
 - (C) Spider gears.
 - (D) Differential cover.
7. Each of the following statements about servicing axle bearings for retainer-type axles is true *except*:
 - (A) they should be removed by first cutting the axle collar with a torch.
 - (B) they should be removed by first cutting the axle collar with a chisel.
 - (C) once the axle collar is removed, the bearing is removed by pressing it from the shaft.
 - (D) if the new bearing presses on with less than 4000 psi (27.58 MPa) of pressure, the shaft should be replaced.
8. Technician A says that the axle must be removed to replace a wheel stud. Technician B says that a press can be used to replace a wheel stud if the axle is removed from the vehicle. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

ASE-Type Questions—Chapter 17

1. Each of the following abnormal noises is typical of those coming from faulty rear axle assemblies *except*:
 - (A) whining.
 - (B) roaring.
 - (C) clunking.
 - (D) squeaking.
2. Each of the following statements about rear drive axles is true *except*:
 - (A) bent axles are a common cause of vibration.
 - (B) vibrations in rear drive axles are always accompanied by noise.
 - (C) bent axles can be checked with a dial indicator.
 - (D) if an axle flange is bent, the axle should always be replaced.

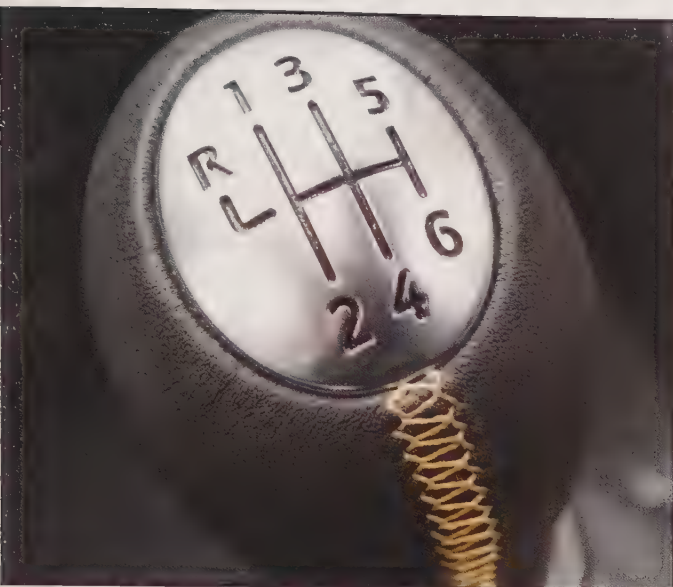
9. Using which of the following tools with a hammer is the best way to install an axle seal?
 - (A) Correct-sized pipe.
 - (B) Wooden block.
 - (C) Seal driver.
 - (D) Correct-sized socket.
10. Technician A says that a limited-slip differential can be checked for proper operation with a torque wrench. Technician B says that improper lubricant can cause limited-slip differential slippage. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
11. Which of the following should be removed last when removing a rear axle assembly?
 - (A) Rear springs.
 - (B) Rear shock absorbers.
 - (C) Drive shaft.
 - (D) Rear wheels.
12. If the ring gear backlash is improperly adjusted, which of the following could occur?
 - (A) Side bearing overheating.
 - (B) Pinion bearing wear.
 - (C) Lubricant leaks.
 - (D) Rear end whining or clunking.
13. Each of the following statements about ring gear contact pattern is true *except*:
 - (A) adjust the side bearing shims or end caps if incorrect contact pattern is caused by too much or too little endplay.
 - (B) changing the pinion shim may be necessary to establish the correct contact pattern.
 - (C) using a heavier-weight lubricant will correct many improper contact patterns.
 - (D) proper ring gear contact pattern is critical to quiet operation and long gear life.
14. Technician A says that when installing a gasket for the differential cover, an anaerobic sealer should be used. Technician B says that form-in-place gaskets should never be used for the differential cover. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.



Some common causes of abnormal noise in the rear axle assembly are a defective axle, improper ring and drive clearance, worn spider or side gears, and worn bearings. (Ford)

Chapter 18

Four-Wheel Drive Component Construction and Operation



After studying this chapter, you will be able to:

- ☐ List the basic parts of a four-wheel drive system.
- ☐ Describe the operation of a four-wheel drive system.
- ☐ Compare transfer case design variations.
- ☐ Explain the construction and operation of a transfer case.
- ☐ Explain the operation of a hydraulic locking transfer case.
- ☐ Explain the operation of an electronic transfer case.
- ☐ Summarize the construction and operation of locking hubs on four-wheel drive systems.
- ☐ Describe four-wheel drive variations.
- ☐ Explain the operation of a range and gear ratio control transfer case.
- ☐ Explain the operation of a range control only transfer case.
- ☐ Explain how power flows through a four-wheel drive system.

Technical Terms

Part-time four-wheel drive system	Transfer case mainshaft	TCCM (Transfer Case Control Module)
Full-time four-wheel drive system	Transfer case oil pump	Electronically controlled transfer case
Transfer case	Sliding clutch sleeve	Automatic four-wheel drive transfer case
Front drive shaft assembly	Central differential	Control loop
Front differential	Viscous coupling	Input sensors
Front drive axle	Multiple plate clutch pack	Output device
Halfshaft	Hydraulic locking transfer case	Locking hubs
Rear drive shaft assembly	Mechanical shift system	Range and gear ratio control transfer case
Rear differential	Vacuum shift system	Range control only transfer case
Rear drive axle	ECM (Electronic Control Module)	
Transfer case housing	PCM (Powertrain Control Module)	

Introduction

Four-wheel drive vehicles are much more common today than they were in the past. This chapter presents the basic operating principles and construction details of typical four-wheel drive systems. The information presented here will enable you to understand the service information in the following chapter. Many of the components discussed in this chapter are similar to those studied in earlier chapters. You should have learned about basic gearing, shift mechanisms, and drive shafts in previous chapters.

Four-Wheel Drive Systems

A four-wheel drive system is a drive train system installed on some vehicles to drive all four wheels instead of just two. Four-wheel drive systems provide for better traction on slippery road surfaces than two-wheel drive systems. Four-wheel drive is needed for off-road operation, and it increases control when driving on icy or wet pavement. Four-wheel drive does not, however, affect driving on dry pavement, and will not improve steering or braking.

In addition to the conventional drive train elements, four-wheel drive systems contain several additional components. Unfortunately, the extra components add to the weight and complexity of the drive train. Also, the drag created by the additional components reduces gas mileage.

There are two major types of four-wheel drive systems. In the original four-wheel drive system, the vehicle operator directly controls the drive train parts that send power to two or four wheels. This system, which is called a **part-time four-wheel drive system**, is used on many vehicles, and is often found on large trucks and off-road vehicles. On some newer vehicles, an on-board computer makes the decisions, and the driver only partially controls the system. Other four-wheel drive systems drive all four wheels at all times. These systems are called **full-time four-wheel drive systems** or all-wheel drive systems. Special drive train components are used in these systems to compensate for differences in speed and traction between the front and rear wheels. The driver has limited or no control over the operation of full-time four-wheel drive systems.

Four-Wheel Drive Components

The drive train components of a typical four-wheel drive vehicle are shown in **Figure 18-1**. The major components of a four-wheel drive system include the following:

- ☐ Clutch.
- ☐ Transmission or transaxle.
- ☐ Transfer case.
- ☐ Front drive shaft assembly.

- ☐ Front differential.
- ☐ Front drive axles.
- ☐ Rear drive shaft assembly.
- ☐ Rear differential.
- ☐ Rear drive axles.

As mentioned in Chapter 6, the clutch is used to engage and disengage the engine and the manual transmission or transaxle. The clutch in a four-wheel drive vehicle operates in the same manner as the clutch in a two-wheel drive vehicle. It is used in the four-wheel drive vehicle only if the vehicle has a manual transmission or transaxle.

The transmission or transaxle provides different gear ratios for varying vehicle and road conditions. Either a manual or an automatic model can be used with four-wheel drive vehicles. The transmission or transaxle used in four-wheel drive systems operates in the same manner as those used in two-wheel drive systems.

The **transfer case** is the mechanical unit that splits power between the front and rear wheels (axles). It is attached to the rear of the transmission or transaxle and receives power from the transmission or transaxle output shaft. Power leaves the transfer case through two output shafts. In addition to various drive gears, transfer cases may contain drive chains, a differential assembly, or a viscous coupling. These items will be covered in detail later in this chapter.

The **front drive shaft assembly** extends from the front of the transfer case to the front differential. It transfers power from the transfer case to the front differential. The front drive shaft assembly has a slip yoke and universal joints. Four-wheel drive vehicles with a front-wheel drive transaxle may not have a front drive shaft assembly.

The **front differential** is a unit designed to transfer power from the front drive shaft assembly to the front wheels. It resembles the rear axle assembly used in a rear-wheel drive vehicle and operates in the same manner. The front differential may be a solid (one-piece) unit or it may be independently sprung. On some vehicles, the differential is an integral part of the transaxle.

The **front drive axles** are connected to the front differential assembly and transfer power from the differential to the front wheels. The front drive axles are straight steel shafts when used with a solid differential assembly. When used with an independently sprung differential, the axles are equipped with cross-and-roller U-joints or CV joints for flexibility. The axle shafts used as independent front axles are sometimes called **halfshafts**.

The **rear drive shaft assembly** extends from the transfer case to the rear axle assembly. It is identical in design and operation to the drive shaft assembly used in two-wheel drive vehicles. Most drive shaft assemblies have at least two universal joints to provide flexibility. They also have a slip yoke to allow for changes in shaft length.

The **rear differential** is identical to that of a rear axle assembly used on a two-wheel drive vehicle. It contains the ring and drive pinion gears and the differential case gears. The rear differential used on trucks is usually the

solid-axle type. Rear differentials used on cars may be solid-axle or, more often, independent designs.

The **rear drive axles** are connected to the rear differential. The axles may be straight shafts, or they may be equipped with cross-and-roller U-joints or CV joints.

Many factors influence the design of a four-wheel drive system such as how the engine is mounted in the vehicle and whether the four-wheel drive system is part-time or full-time. The design of the four-wheel drive system used with a longitudinal (conventional) engine is shown in **Figure 18-1A**. The engine, transmission, drive shaft assembly, and rear axle assembly are placed as they would be in a two-wheel drive vehicle. However, a transfer case is installed between the transmission and the rear drive shaft. A front drive shaft assembly, with U-joints and a slip yoke, connects the transfer case to the front axle assembly.

The front axle assembly contains a differential unit that is similar to the one used in the rear axle assembly. The front axle shafts may be solid or independent.

Figure 18-1B shows the arrangement of drive train parts on a vehicle with a transverse engine. The engine and transmission are mounted in the same way as they would be in a two-wheel drive vehicle. The transfer case is mounted on the transaxle. In some cases, the transfer case is an integral part of the transaxle. The front and rear outputs from the transfer case go to the front and rear axles. A long drive shaft connects the transfer case to the rear axle. The front differential unit and the transfer case are often installed into a single split housing. This arrangement eliminates the need for a front drive shaft.

In some four-wheel drive systems, some method of selecting two- or four-wheel drive must be provided. The

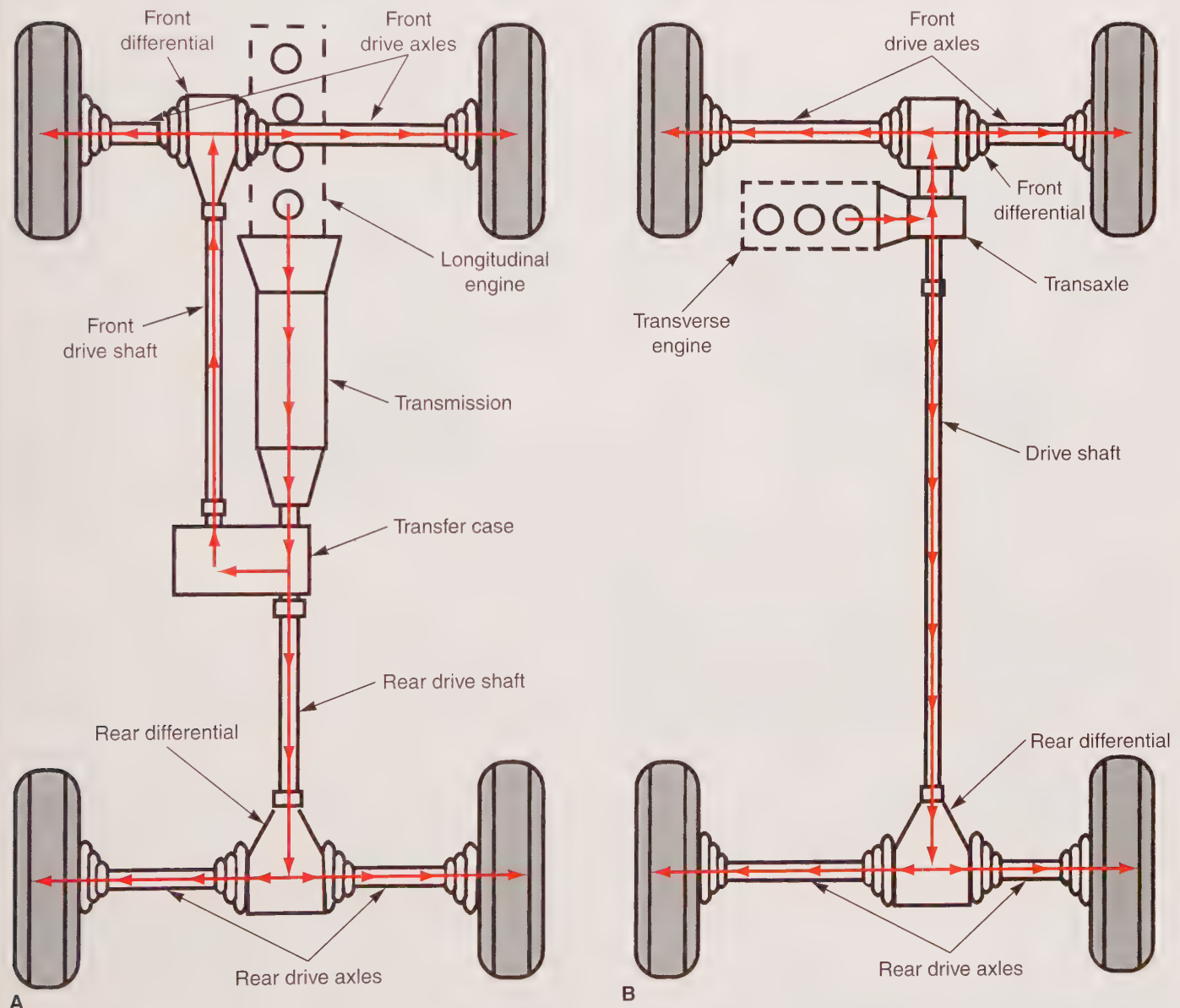


Figure 18-1. Layout of a four-wheel drive system depends on the engine position. A—System used with a longitudinal engine and a rear-wheel transmission. B—System used with a transverse engine and a front-wheel transaxle. Note that this system does not contain a separate transfer case. The system shown in A is much more common than the one shown in B.

standard part-time four-wheel drive system is controlled by the driver by either turning special front-wheel hub locks or by moving a lever in the passenger compartment. This type of control system is usually found on vehicles designed for off-road use. Modern vehicles use an on-board computer to select drive systems.

As previously mentioned, vehicles designed primarily for on-road use have a more sophisticated four-wheel drive system that constantly drives all four wheels. **Figure 18-2** illustrates the difference between full-time and part-time four-wheel drive systems.

A full-time four-wheel drive system that is equipped with a central differential to compensate for differences in speed between the front and rear axles is shown in **Figure 18-3**. If one drive shaft is turning faster than the other, the differential action allows the vehicle to operate normally. The operation of differential assemblies was discussed in Chapter 16.

To prevent wheel spin at the axle with the least amount of traction, full-time four-wheel drive systems may be equipped with a limited-slip or locking differential, a centrally mounted viscous coupling (instead of a differential unit), a combination of a coupling and a differential, or a clutch pack. The rest of this section details the various components found in four-wheel drive vehicles.

Transfer Case

A transfer case is a cast metal housing that contains shafts, gears, bearings, and other parts. The transfer case can be compared to a transmission or transaxle because it has many of the same parts. The transfer case resembles the transaxle in that it has one input shaft and two output shafts. Many of the internal transfer case parts will be

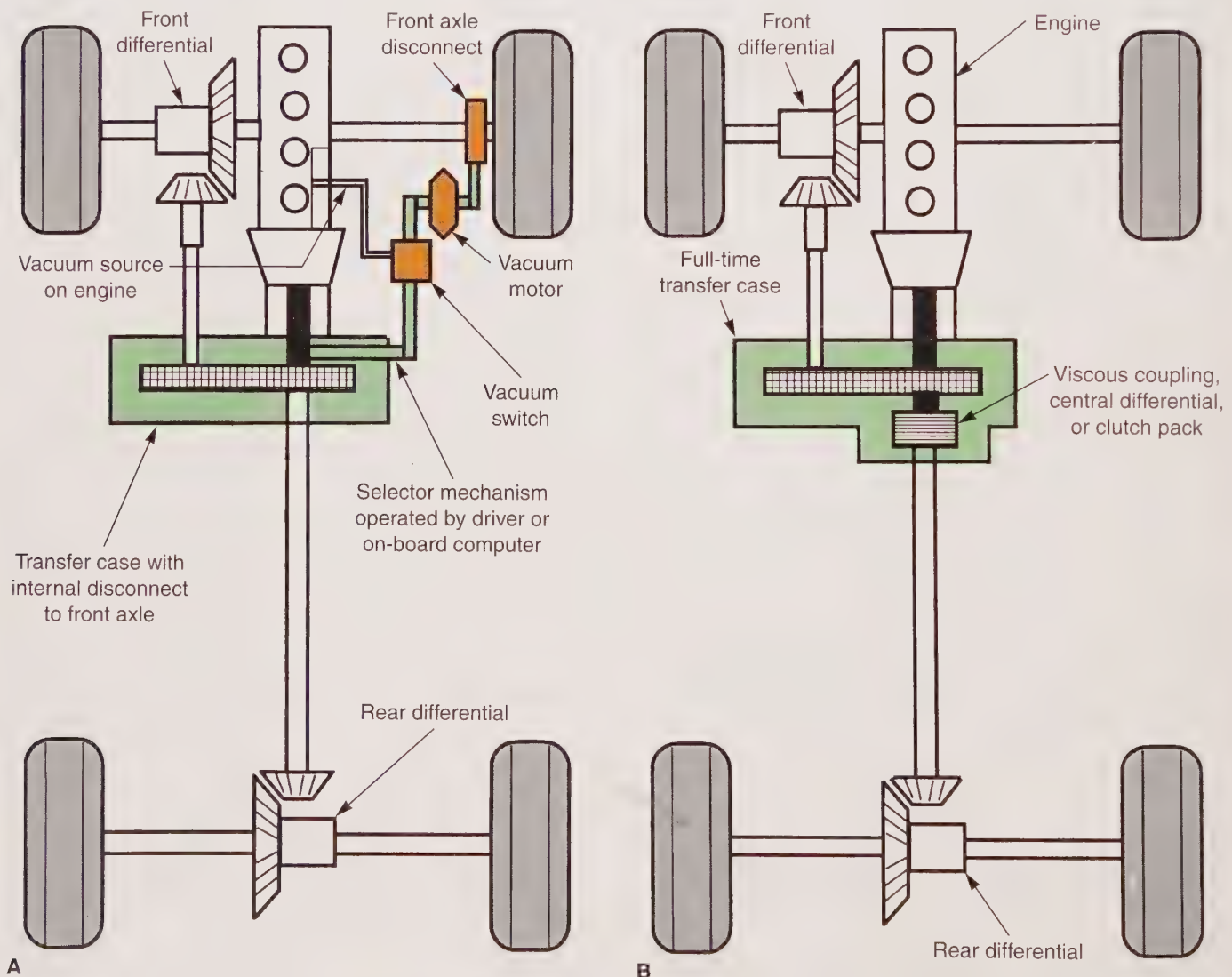


Figure 18-2. Four-wheel drive vehicles are available with either part-time or full-time systems. A—The part-time system has a selector mechanism to engage the front wheels and to provide high and low gear ratios as needed. The mechanism shown here is vacuum operated. Other systems are operated by electric motors and an electronic control system. B—The full-time system is not controlled by the driver. All wheels are driven whenever the vehicle is moving.

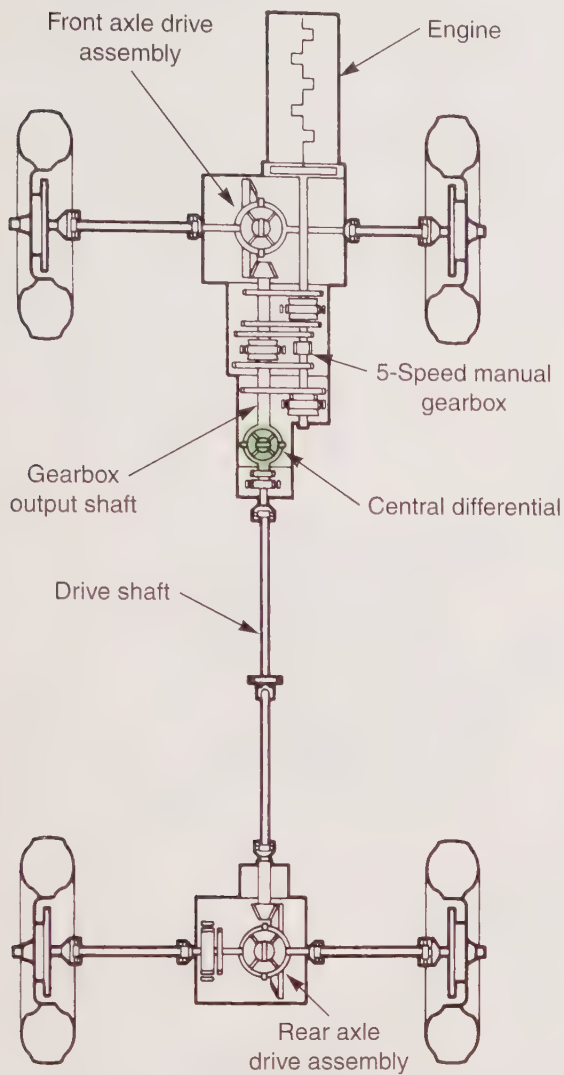


Figure 18-3. The full-time four-wheel drive system constantly drives all four wheels. The central differential unit compensates for different speeds of the front and rear wheels. (Audi)

familiar to anyone who has serviced transmissions and transaxles. Since there are major differences between various transfer case manufacturers, pay particular attention to the parts covered in the following section. Keep in mind that not every transfer case has all of these parts.

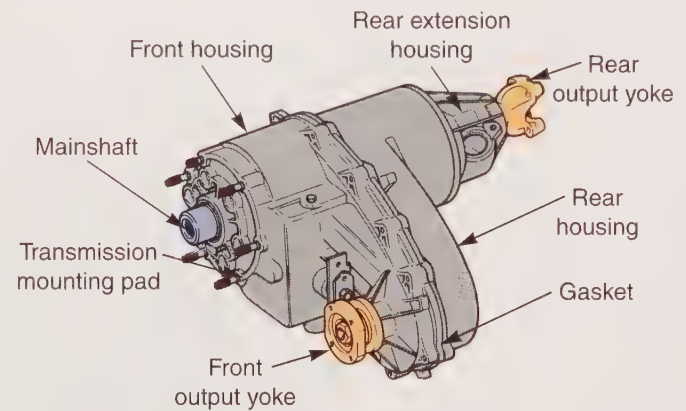
Transfer Case Housing and External Components

The **transfer case housing** holds and aligns the transfer case shafts, gears, chains, and bearings. The housing also serves as a reservoir for the lubricating oil. Transfer case housings are usually made of cast iron, aluminum, or magnesium and are strengthened with cast ribs or external bracing rods. Manufacturers make the housing as compact as possible. This reduces stresses and allows the chassis of the four-wheel drive vehicle to be almost as close to the ground as the chassis of a two-wheel drive vehicle.

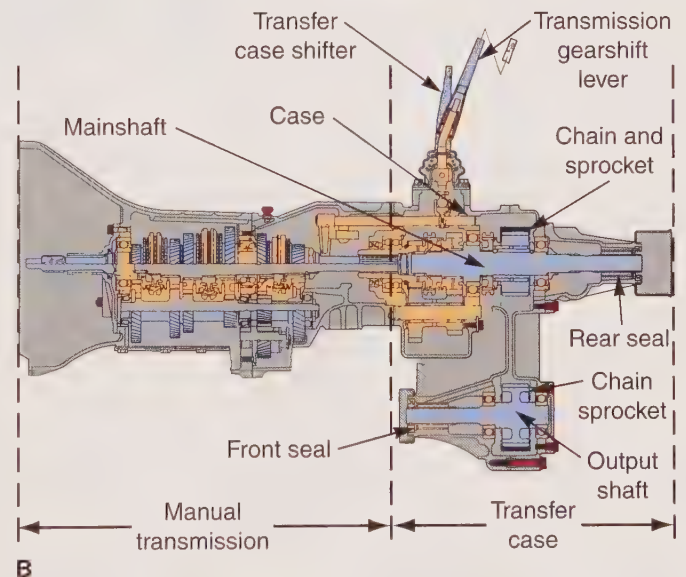
The transfer case housing used with a longitudinal engine is usually a two-piece design, so that it can be taken apart for service. A typical housing is shown in **Figure 18-4A**. One end of the housing mounts to the rear of the transmission. Gaskets at the case halves and between the case and transmission prevent oil leaks. The front and rear output yokes have seals to prevent oil loss.

Figure 18-4B is a cutaway view of a typical transmission and transfer case used with a longitudinal engine. When a shift lever is used, it extends into the transfer case to operate the shift forks. Other components, such as speedometer gears or electrical switches, may be installed in or mounted on the transfer case.

One particular transfer case that is used with a transaxle is illustrated in **Figure 18-5A**. It is actually a small differential unit with bevel gears that turn the power 90°. **Figure 18-5B** shows this type of transfer case installed on a transaxle. This transfer case drives the rear wheels only; the front wheels are

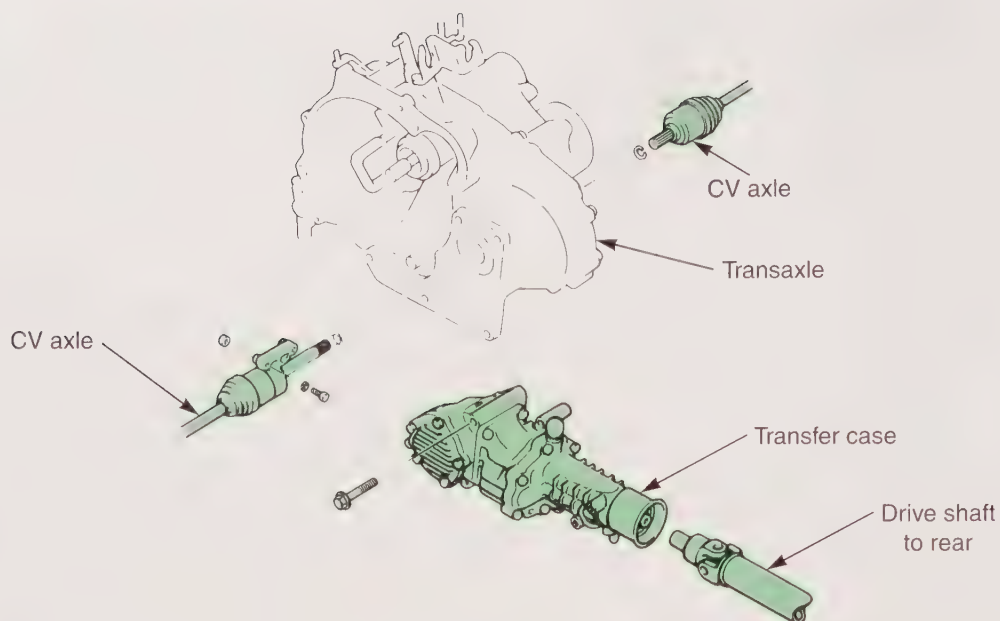


A

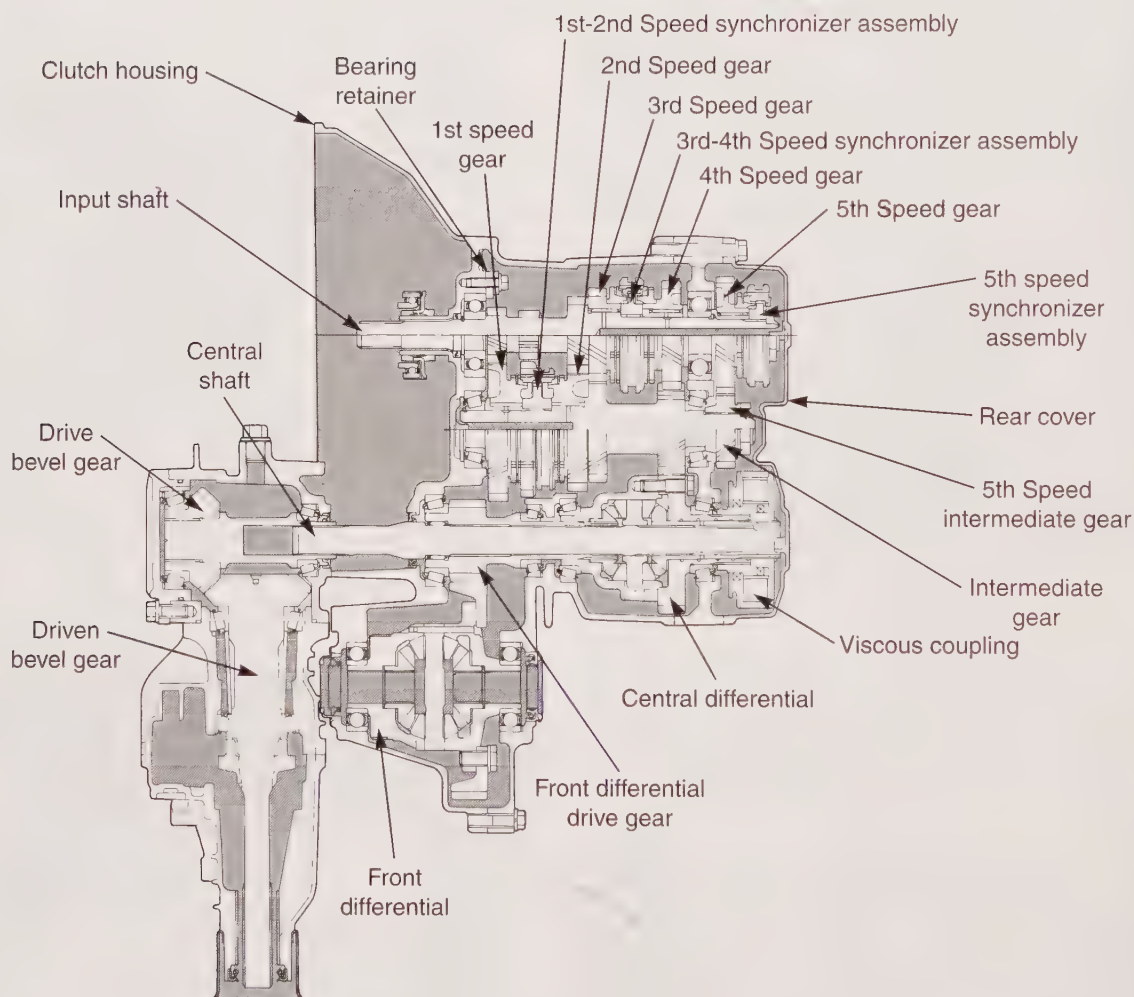


B

Figure 18-4. The transfer case is the heart of the four-wheel drive system. It divides engine power between the front and rear wheels. A—Transfer case used with longitudinal engine and rear-drive transmission. B—This cutaway shows the arrangement of the transfer case and the transmission. (Chrysler, General Motors)



A



B

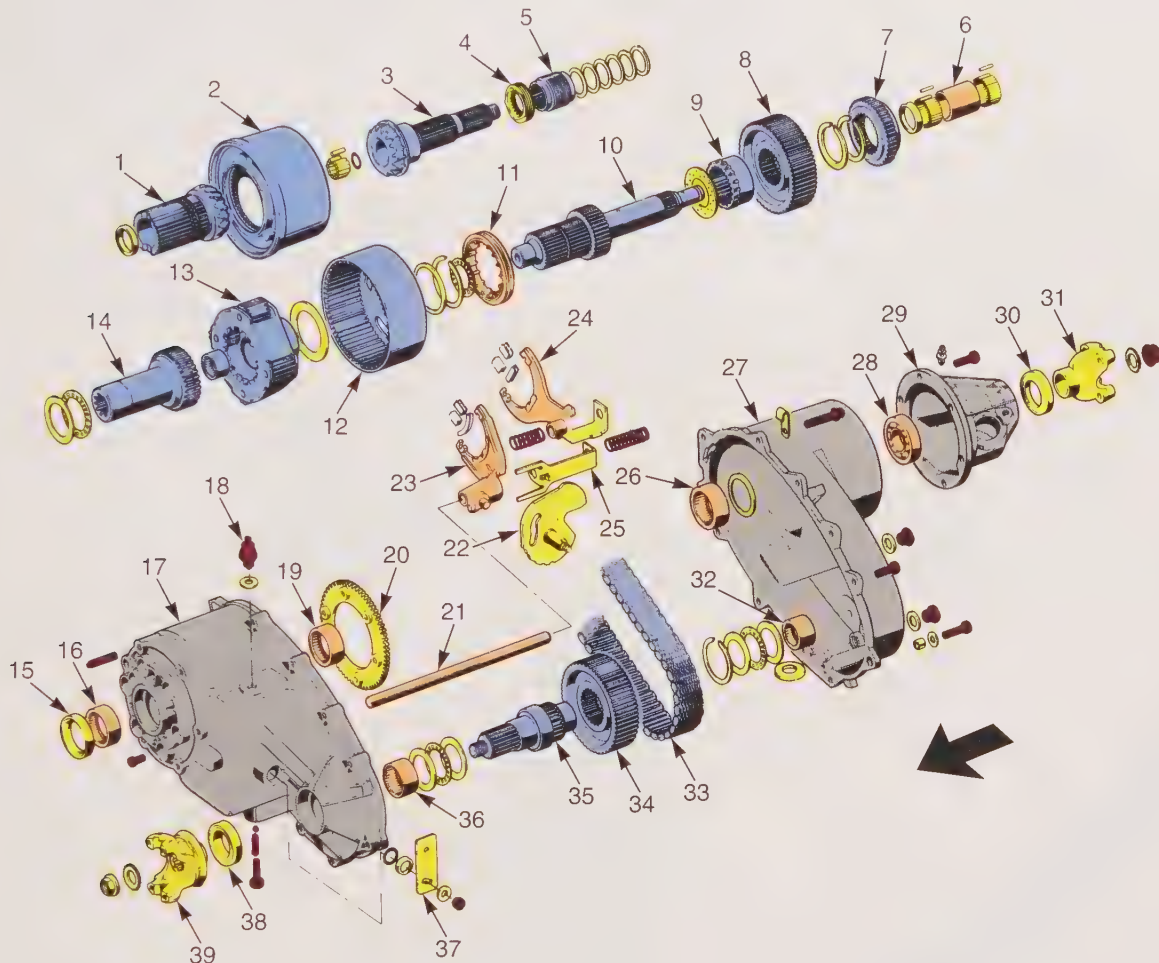
Figure 18-5. A—This transfer case is used with a front-wheel drive transaxle. It connects the transaxle output with the rear wheels. The transaxle differential assembly delivers power to the front wheels through the CV axles. B—Cutaway view of a transfer case used with a front-wheel drive transaxle showing the relative positions of the parts. The bevel gears rotate engine power 90° to turn the rear drive shaft. (Chrysler)

driven by the transaxle. Other transfer cases used with transverse engines drive both the front and rear wheels.

Internal Transfer Case Parts

There are many variations of the drive mechanisms used in a basic transfer case. **Figure 18-6** shows a complex transfer case, which contains many parts. This transfer case can provide two- or four-wheel drive and reduction gear drive or direct drive. Other transfer cases are simple,

with only three spur (straight-cut) gears. All-wheel or full-time four-wheel drive systems usually have a single-speed transfer case. Part-time four-wheel drive transfer cases usually have a method of changing gear ratios to obtain a low gear in four-wheel drive. The major internal components of a typical transfer case include the input shaft, output shafts, oil pump, gears, and drive chain (if used). Other internal parts used on some transfer cases include planetary gears, viscous couplings, differential assemblies, and clutch packs.



- | | | |
|---|--------------------------------|--------------------------------------|
| 1. Side gear | 14. Input gear | 28. Rear output bearing |
| 2. Viscous coupling and differential assembly | 15. Input gear oil seal | 29. Rear retainer |
| 3. Rear output shaft | 16. Input gear front bearing | 30. Output shaft oil seal |
| 4. Oil pump | 17. Front case | 31. Rear yoke |
| 5. Speedometer gear | 18. Lock mode indicator switch | 32. Front output shaft rear bearing |
| 6. Mainshaft rear bearing spacer | 19. Input gear rear bearing | 33. Drive chain |
| 7. Clutch gear | 20. Low range lockplate | 34. Driven sprocket |
| 8. Drive sprocket | 21. Shift rail | 35. Front output shaft |
| 9. Side gear clutch | 22. Range sector | 36. Front output shaft front bearing |
| 10. Mainshaft | 23. Range fork | 37. Operating lever |
| 11. Clutch sleeve | 24. Mode fork | 38. Front output shaft seal |
| 12. Annulus gear | 25. Mode fork bracket | 39. Front yoke |
| 13. Planetary assembly | 26. Rear output shaft bearing | |
| | 27. Rear case | |

Figure 18-6. The planetary gears and the viscous coupling identify this transfer case as one designed for full-time operation. Compare this illustration with Figure 18-2B. (Chrysler)

Input shaft and oil pump

The **transfer case input shaft**, sometimes called the **mainshaft**, is shown in **Figure 18-7**. The input shaft receives power from the transmission or transaxle and transfers it to the other transfer case components. The **transfer case oil pump**, shown in **Figure 18-8**, is used to provide lubricating oil to various transfer case components. It is not used to produce hydraulic pressure, since the transfer case components operate without hydraulic pressure.

Many transfer cases do not have oil pumps. They depend on oil splash for lubrication. To reduce lubrication demands, most transfer case bearings are ball or roller bearings. Tapered roller bearings and thrust bearings (Torrington bearings) are also used.

Transfer case drive mechanisms

Many types of transfer case drive mechanisms have been used over the years. Drive mechanisms can be classified as either gear drives or chain drives. Older transfer cases used the gear drive. Gear drive transfer cases have an arrangement of spur or helical gears to produce two- and four-wheel drive and provide different gear ratios. Newer transfer cases use a chain and sprockets to provide two- and four-wheel drive, sometimes combined with gears to provide low and high ratios.

Gears can be used to obtain two- or four-wheel drive and to select high and low ranges in a transfer case. The gears must be engaged and disengaged to select different drives and gear ratios. The gears may be moved in and out

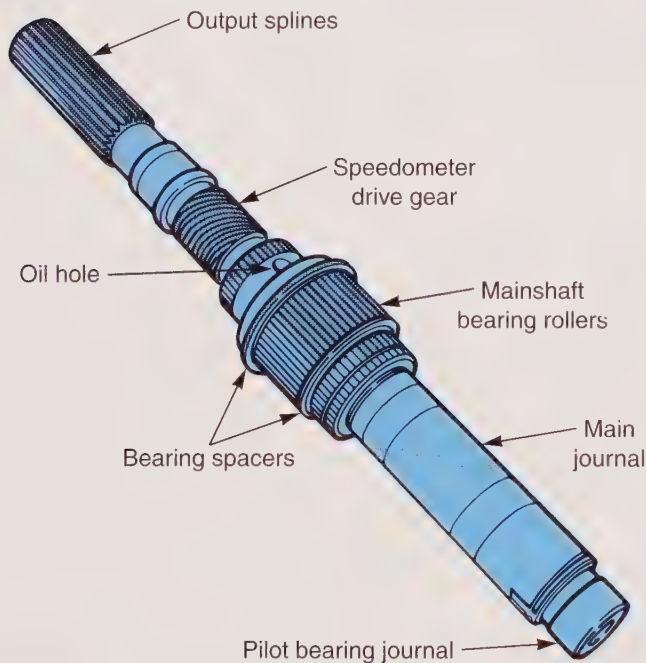


Figure 18-7. The transfer case mainshaft resembles the input shaft used in transmissions and transaxles. It contains splines that mesh with the other transfer case components. (Chrysler)

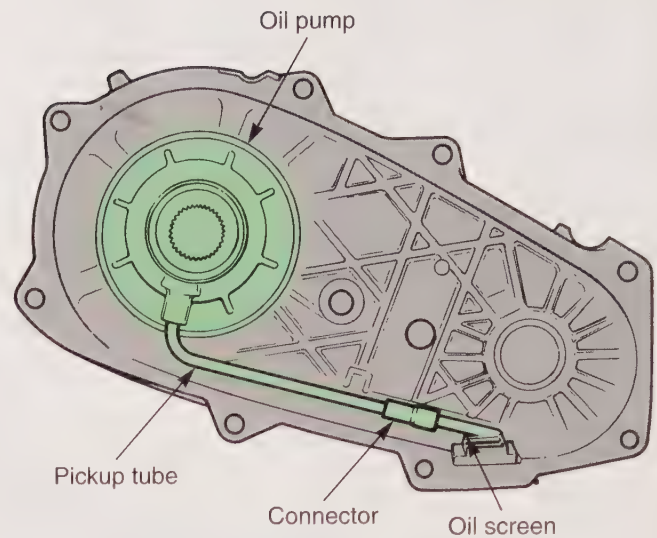


Figure 18-8. Some transfer cases use an oil pump to lubricate moving parts. An oil pump with a sump pickup tube is shown here. The pickup tube allows the pump to draw oil from the bottom of the case. Transfer cases that do not have an oil pump depend on oil splash for lubrication. (Chrysler)

of engagement. On some newer transfer cases, the gears are controlled by a sliding clutch assembly, similar to a synchronizer assembly used on a manual transmission. The sliding clutch assembly may have blocking rings to eliminate gear clash. A gear drive transfer case is shown in **Figure 18-9**.

Figure 18-10 illustrates a simple chain drive. The advantages of a chain drive are compactness and the elimination of the need for an idler gear to maintain proper output shaft rotation. The chain drive assembly consists of a chain and two sprockets. The sprocket that delivers power to the chain is called the drive sprocket. The input shaft drives this sprocket, sometimes directly, sometimes through a gear assembly. The other sprocket, which receives power from the chain, is called the driven sprocket. This sprocket drives the output shaft. See Chapter 4 for additional information on chain drives.

Most drive chains used in transfer cases are multiple leaf chains, which are commonly called silent chains. Increasing the width of the chain increases its load-carrying capacity. See **Figure 18-11**. A chain drive transfer case may have gears to change the gear ratio.

Planetary gears can be used with either gear or chain drives to provide different transfer case gear ratios. The planetary gearset is usually installed between the transfer case input shaft and the gear or chain drive mechanism. The advantage of using planetary gears in the transfer case is that the gears provide a compact way to transfer power and provide different gear ratios. Since they do not go in and out of mesh, planetary gears are less likely to be damaged. Planetary gears are used extensively in automatic transmissions, where they are operated by hydraulic pressure. The planetary gears used in transfer cases are mechanically selected by

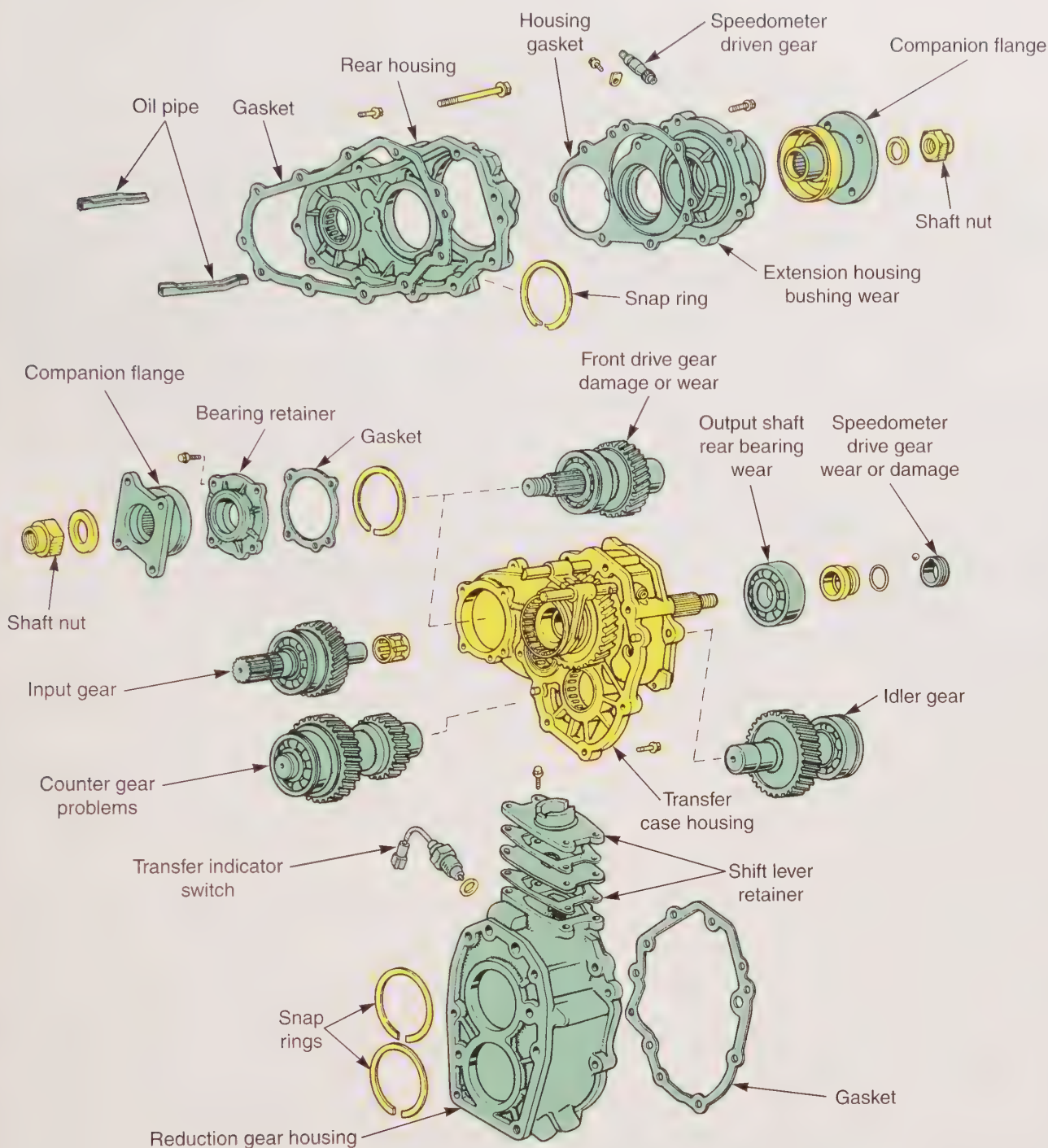


Figure 18-9. An exploded view of a typical gear drive transfer case. Note the internal parts. Gear drive transfer cases have several gears to obtain 2- and 4-wheel drive and different gear ratios. (Toyota)

moving the **sliding clutch sleeve**, or **shift collar** as it is sometimes called, in and out of engagement. For more information on planetary gear basic principles, see Chapter 4.

output shaft. The output shafts are attached to the drive yokes. The shafts and yokes have matching splines. A large nut is used to secure the yoke to the output shaft.

Output Shafts

The front and rear output shafts are connected to the transfer case gearing or to the driven sprocket, depending on the design of the transfer case. The output shaft to the rear of the vehicle is often an extension of the transmission

Central Differential and Viscous Coupling

The central differential and the viscous coupling are designed to compensate for differences in front and rear wheel speeds. They are almost always used on full-time four-wheel drive vehicles.

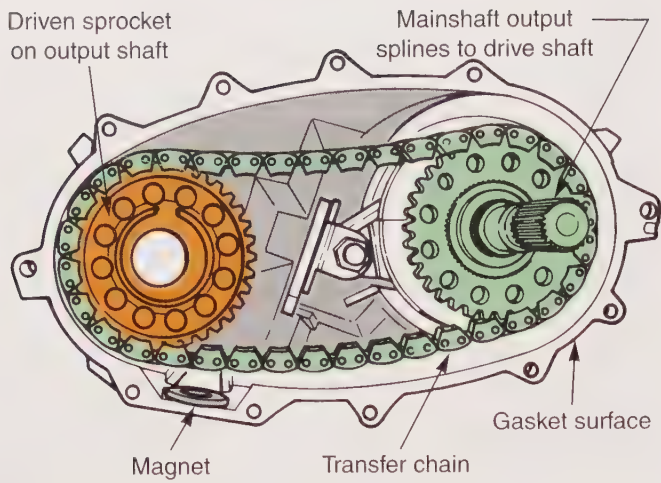


Figure 18-10. A drive chain and sprockets are often used in transfer cases to transfer power. Chain drives are compact and transfer rotation from the drive sprocket to the driven sprocket without reversing it. The drive sprocket is driven by the same shaft that turns the rear drive shaft, and the driven sprocket turns the front drive shaft. (Chrysler)

The **central differential** compensates for changes in speed as the spider gears walk around the side gears, **Figure 18-12A**. Because the central differential can spin and drive the axle with the least amount of traction, the differential gears must be locked in some way when necessary. A few manufacturers use a driver-controlled lockout, which is often vacuum operated. However, this type of system is seldom used on cars or light-duty trucks.

To eliminate slippage, some manufacturers use a locking or limited-slip central differential. **Figure 18-12B** shows a Torsen® central differential. The design of this differential's worm-and-wheel gears prevents spinning and sends power to the axle with the most traction. The gears can turn to allow slight differences in axle speeds. This type of differential was discussed in Chapter 16.

The **viscous coupling** is a series of alternately splined plates that often have small ridges or other indentations. Refer to **Figure 18-12A**. A few viscous couplings use sets of vanes. Half of the plates or vanes are splined to the input side of the coupling, and half are splined to the output side. The plates are close together, but they do not touch. Therefore, there is no mechanical connection between the input and the output sides of the coupling. The space between the plates is filled with a thick liquid, such as silicone. The liquid is thick enough to allow the input plates to drive the output plates. Seals keep the liquid from leaking out of the coupling and mixing with the transfer case oil.

Since the input and output plates are not locked together, the liquid allows them to slip slightly when there is a difference between front and rear axle speeds, such as when the vehicle makes a turn, allowing the vehicle to

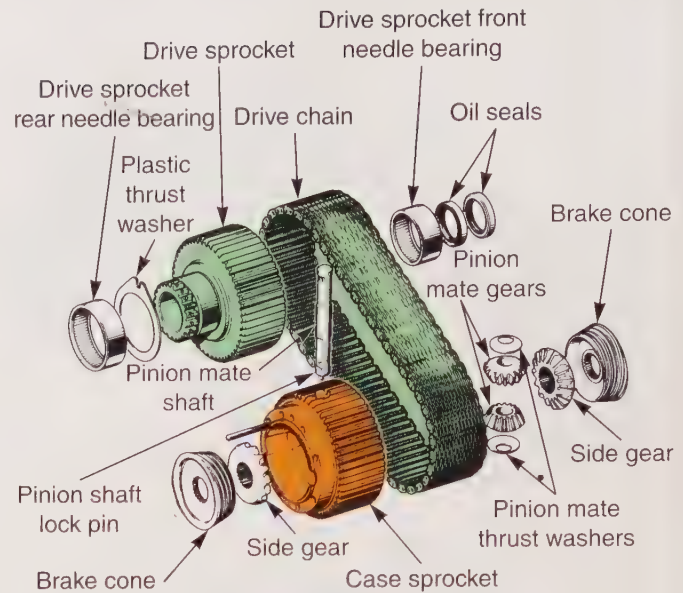


Figure 18-11. Wide, multiple-leaf chains are used to transfer power in many transfer cases. The large chains are able to handle high engine horsepower. (Chrysler)

operate normally. Also, if one axle loses traction and begins spinning, the viscous coupling continues to send power to the axle with traction.

Figure 18-13 shows a typical viscous coupling attached to the rear output shaft. Although central differentials and viscous couplings are often used together, they can be used separately.

Multiple Plate Clutch Pack

Some transfer cases have a multiple plate clutch pack. A **multiple plate clutch pack** is a series of clutch plates, **Figure 18-14**. These clutch plates perform the same job as a single plate manual clutch but look and operate somewhat differently. Half of the clutch plates have internal splines, and half have external splines. The clutch plates are arranged with internal splined plates alternating with external splines. The internal splines mate with splines on the rear wheel output shaft. The external splines mate with splines on a drum connected to the input chain drive sprocket.

Pressing the clutch plates together causes them to be applied, or to be locked together. With the clutch pack applied, the rear wheel output shaft and chain drive input sprocket are locked together and turn as a unit. This causes the drive chain to deliver power to the front output shaft. The front and rear output shafts begin turning at the same speed.

Clutch packs on modern transfer cases can be applied by hydraulic pressure or by a shift fork operated by an electric motor. These application methods will be discussed later in this chapter.

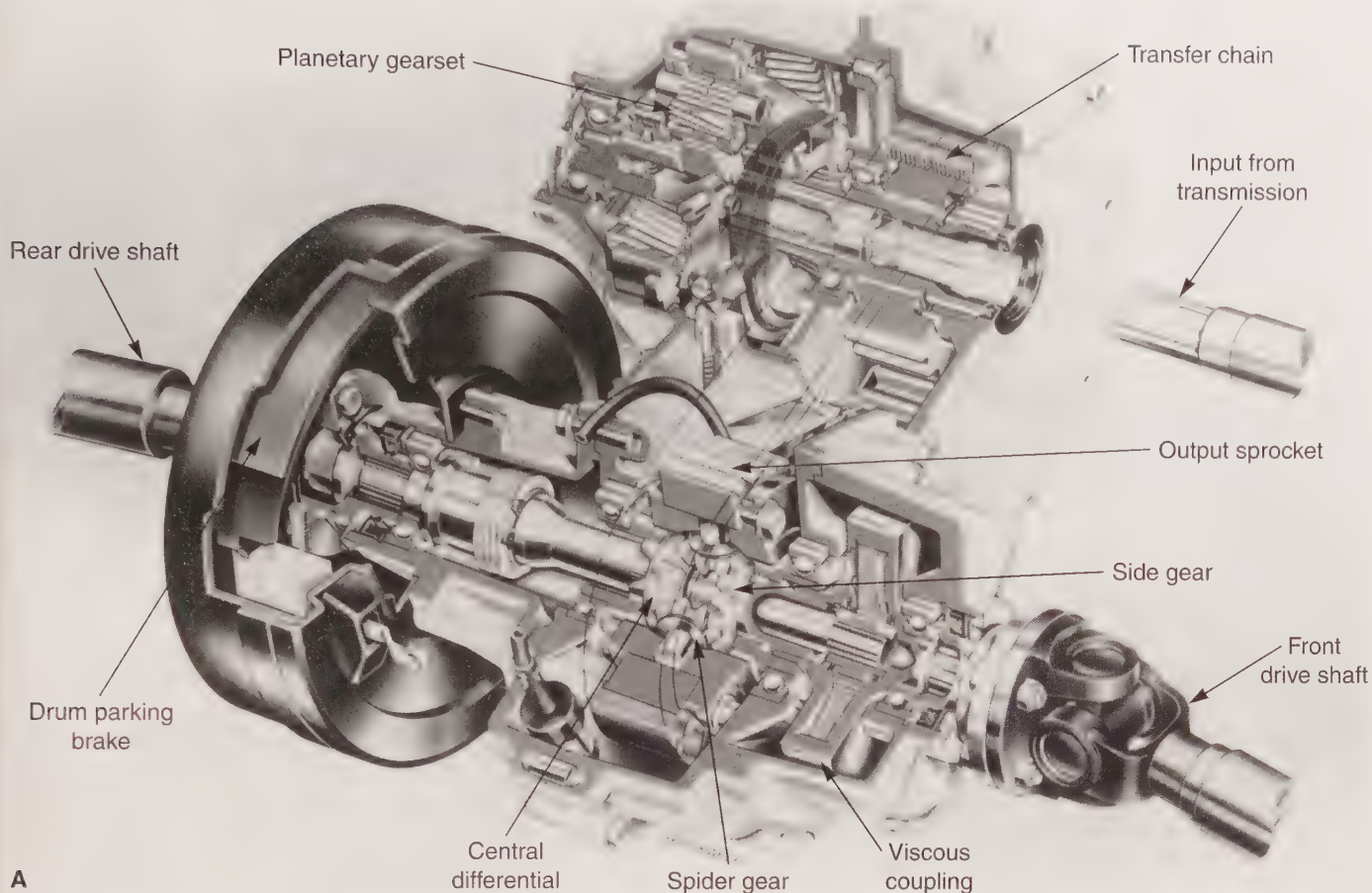


Figure 18-12. The central differential and the viscous coupling provide smooth power transfer at all times. A—The system shown uses a combination of a differential and a viscous coupling. The differential allows for changes in axle speeds, and the coupling prevents wheel slippage. (Land Rover, Audi) (continued)

Hydraulic Locking Transfer Case Components

A **hydraulic locking transfer case**, **Figure 18-15**, uses a hydraulic pump, ring diaphragm, and clutch pack. This pump, ring diaphragm, and clutch pack design is identical to that used in hydraulic locking differentials discussed in Chapter 16. Operation is also similar.

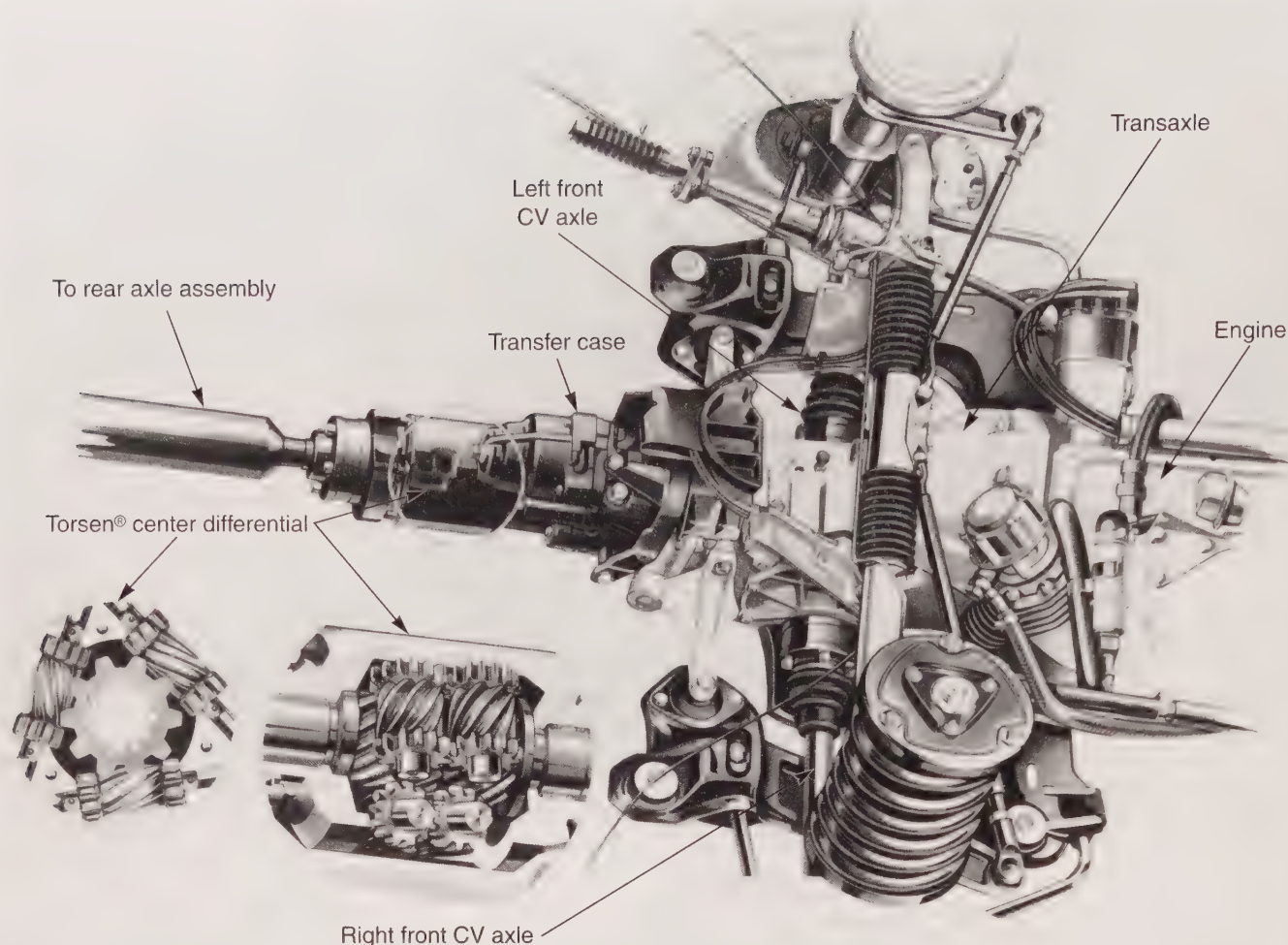
The external gear of a hydraulic locking transfer case is attached to the rear drive shaft. The internal gear is attached to the drive sprocket of the chain assembly. When the front and rear axles have equal traction, both axles turn at the same speed. The internal and external pump gears do not move in relation to each other, and the pump develops no pressure. When the rear axle loses traction, the rear drive shaft begins turning faster than the front drive shaft. The difference in shaft speeds causes the internal and external pump gears to move in relation to each other, producing hydraulic pressure. This pressure is delivered to the ring diaphragm, which expands against the clutch pack. This applies the clutch pack. Power is delivered to the chain drive sprocket, the chain and the driven sprocket, and the front drive shaft. The front and rear axles are locked together and turn as a unit. When the wheels begin turning at the same speeds, the internal and external gears

do not move in relation to each other and no pressure is produced. With no pressure being produced, the ring diaphragm is depressurized and releases the clutches. If one axle again begins to slip, there is a difference in shaft speeds, the pump starts operating again, and the system reapplies the clutches.

Transfer Case Shift Mechanisms

Part-time four-wheel drive systems must have some kind of shift mechanism to allow the driver to select various gears and driving modes. Shift mechanisms can be mechanical or vacuum operated. A few late-model vehicles are equipped with transfer cases that are shifted by electric solenoids or motors. The solenoids or motors are controlled by the driver or by an on-board computer. Most full-time four-wheel drive systems do not have a shift linkage.

Many vehicles have simple **mechanical shift systems** that resemble the shift mechanisms used on manual transmissions. A shift lever that operates the shift rails of a transfer case is shown in **Figure 18-16A**. Because the transfer case is often mounted directly under the shift lever, the linkage can be simple and direct.



B

Figure 18-12 (continued). B—The Torsen differential is a locking differential that takes the place of the standard differential and viscous coupling. It prevents slippage through the design of its gears. (Land Rover, Audi)

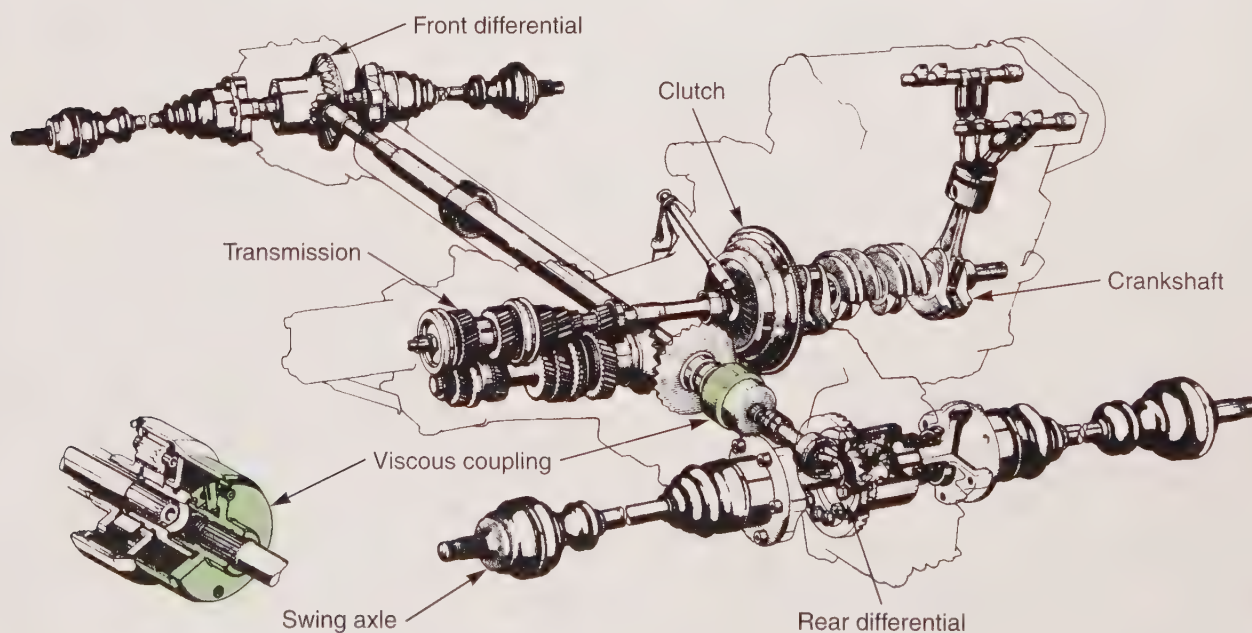


Figure 18-13. This four-wheel drive system used with a transverse mid-engine uses a viscous coupling without a central differential. The fluid in the viscous coupling compensates for differences in axle speeds and prevents excess slippage. (Peugeot)

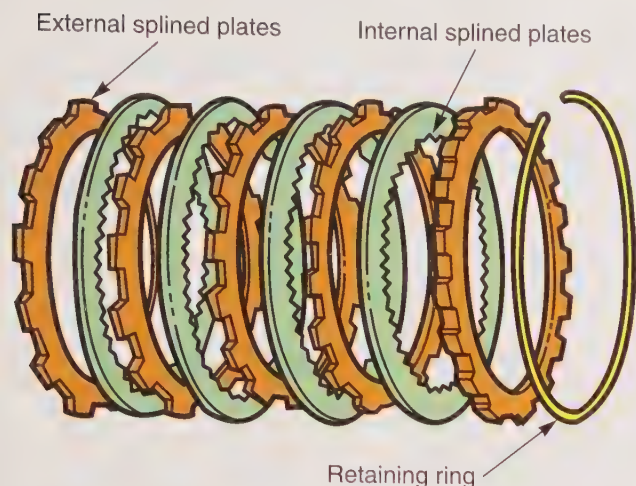


Figure 18-14. This exploded view of a multiple plate clutch shows all the components that make up a common clutch pack. Clutch packs can be used to transmit power or to lock parts of the gear train to the case. (Ford)

Figure 18-16B shows typical shift rails and forks used in transfer cases. Note the resemblance to the rails and forks used in manual transmissions. The forks operate the sliding clutch sleeves that select various gear ratios.

Some vehicles are equipped with a **vacuum shift system**, which disconnects the front axle from the drive shaft when the vehicle is in the two-wheel drive mode. See **Figure 18-17A**. Operation of a vacuum diaphragm moves the shift fork and shift collar, connecting or disconnecting the shafts. The vacuum diaphragm can be operated by the movement of the shift lever or by a dash-mounted switch. Sometimes, vacuum diaphragms are mounted on the transfer case to operate the shift collars inside the case. **Figure 18-17B** is an exploded view of a typical vacuum

Figure 18-15. This cutaway of a hydraulic locking transfer case shows the hydraulic pump and clutch pack. The pump and clutch pack lock the front and rear axles together. This causes the axles to turn at the same speed. (Chrysler)

shift system with a dashboard switch and an indicator light. The engine intake manifold provides the vacuum to operate the diaphragm. A reservoir holds vacuum in case the engine vacuum is low when the diaphragm is activated.

Other vehicles use an electronic shift system. In this system, electric motors are used to connect and disconnect the front axle from the front drive shaft. Electric motor-operated shift forks are usually used with electronic shift systems, which are discussed later in this chapter.

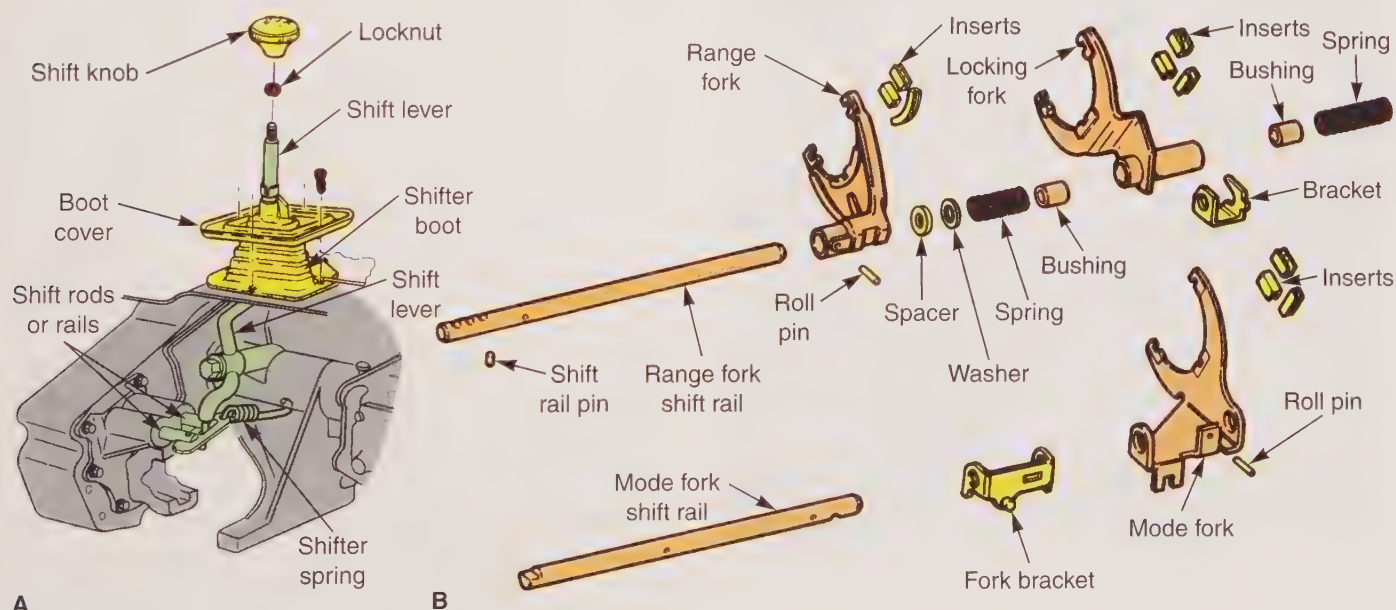


Figure 18-16. The shift linkage for most transfer cases is simple and direct. A—The shift lever and linkage are usually located on top of the transfer case. The lever is sealed at the vehicle floor by a flexible boot. B—The shift forks are attached to the shift rail and operate the sliding clutch sleeves in the transfer case. (General Motors)

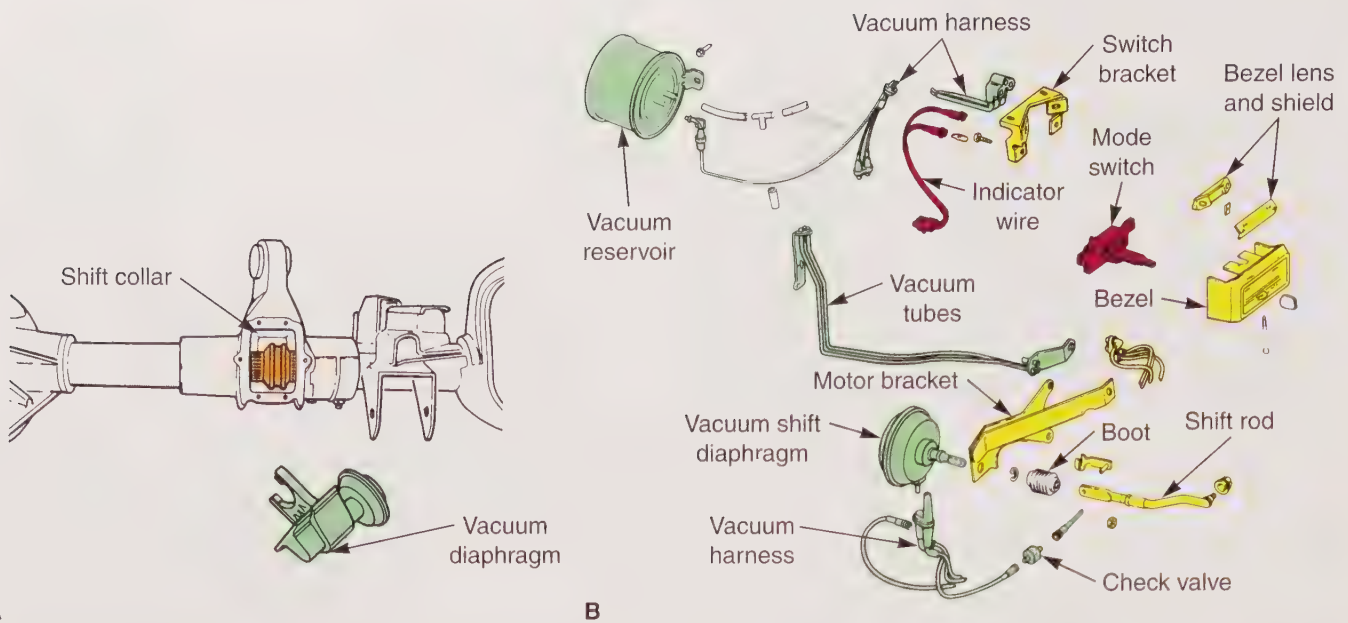


Figure 18-17. Some vehicles have vacuum-operated shift systems that use a vacuum diaphragm to operate one or more shift forks. **A**—This vacuum diaphragm operates the shift collar that connects and disconnects the front axles from the transfer case. **B**—This vacuum shift system consists of the vacuum diaphragm, vacuum source (on the intake manifold), control switch, indicator light, and a vacuum tank that acts as a reservoir. (Chrysler)

The transfer case shift lever is usually mounted near the transmission gearshift lever, as shown in **Figure 18-18**. Some shift levers are mounted on the dashboard. Push-buttons are used to control transfer case shifting on electronic shift systems.

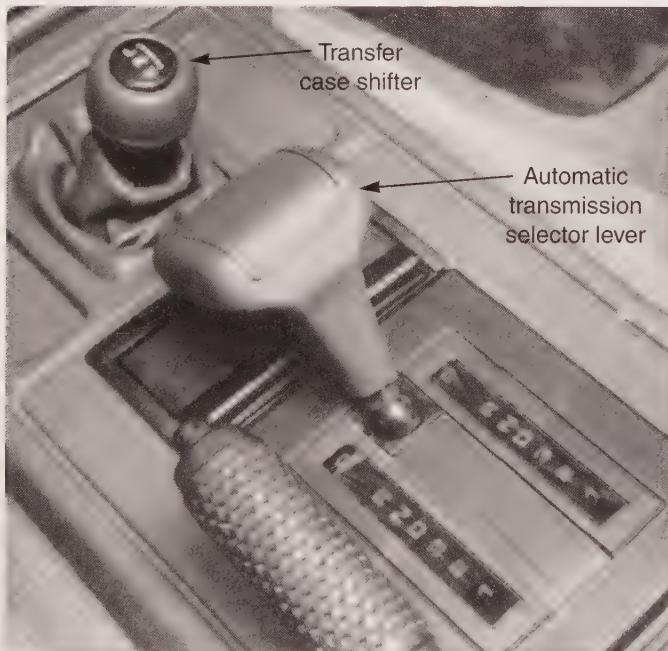


Figure 18-18. The transfer case shift lever is generally located near the transmission gearshift lever on the shifter console. Some modern systems use dash-mounted switches to activate a shifting mechanism. Most full-time systems do not have driver-operated controls. (Land Rover)

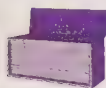
Electronic Transfer Case Components and Operation

On many four-wheel drive vehicles, manual shifting has been eliminated. These vehicles have electronic transfer cases and use on-board computers to select transfer case ranges and gear ratios. As with manual part-time transfer cases, the purpose of an electronically controlled transfer case is to select either two- or four-wheel drive at the right final drive ratio to provide the best traction for any road condition. The electronic transfer case makes selections without requiring the driver to make decisions or operate levers.

The internal components of an electronic transfer case are similar to those in a manually operated transfer case. In electronic transfer cases, the driver-operated levers are replaced with input sensors and electric motors. The sensors provide the computer with information about engine and road speed, wheel slippage, and other operating parameters. The computer processes this information and issues commands called outputs to the motors. The motors then move the transfer case shift forks to select the proper range. On some systems, the computer operates a motor on the front axle to engage and disengage the front axle shafts from the transfer case. The computer also illuminates dashboard indicator lights to inform the driver of the range selected and warn of a system malfunction.

Some manufacturers use a single computer called an **ECM (electronic control module)** or a **PCM (powertrain control module)** to operate the engine, transmission, and transfer case. Others use a separate computer called **TCCM (transfer case control module)** to operate the transfer case. The TCCM interacts with other vehicle computers to send and receive information. Typical inputs from other vehicle

computers include engine speed and load, engine temperature, transmission gear, and wheel speed.



Note: The transfer case control computer will be referred to as the ECM in the remainder of this chapter and in Chapter 19.

Driver inputs are routed through the ECM as a safety feature. If the driver attempts to make an improper selection, such as putting the transfer case in four-wheel drive at high vehicle speeds, the ECM will ignore the selection until it can be completed safely. In the above example, the ECM would perform the shift to four-wheel drive when vehicle speed was reduced to the point where it could be done without damaging the drive train or causing the driver to lose control. To perform this safety function, the ECM relies on inputs from vehicle speed sensors and other drive train sensors.

On some vehicles, the ECM is simply a relay for driver commands and does not make its own decisions regarding range selection. The driver selects the transfer case range on this type of system by pressing dashboard-mounted switches or moving a floor-mounted lever. These transfer cases are called **electrically controlled** or **electronically controlled** transfer cases.

On other transfer cases, the ECM makes most decisions and the driver does not select the necessary range. This type of transfer case is called an **automatic four-wheel drive transfer case**. Some transfer cases are combination units. In a combination transfer case, the driver can manually select some ranges or place the system in automatic mode and let the ECM make the range selections.

The components of the electronic transfer case form a **control loop**. A control loop is a continuous series of inputs, ECM decisions and actions, and outputs. The ECM bases its decisions on signals received from **input sensors**. The most important inputs come from speed sensors. Speed sensors are installed on the transfer case and measure the speed of the front and rear output shafts. A speed sensor consists of a small wire coil surrounding a permanent magnet. A toothed wheel installed on the rotating shaft generates a small alternating current in the wire coil. Higher speeds increase the frequency of the AC signal. The ECM reads this change in frequency as a speed signal.

On some systems, other inputs come from position switches on the transfer case. On some transaxles, the shift motor contains position switches. This kind of motor may be referred to as a motor-encoder. These inputs tell the ECM the current transfer case range. Other inputs tell the ECM the transmission gear and whether the brakes are applied.

The ECM analyzes the sensor inputs and uses them to decide what output commands are needed. Output commands are sent to the **output devices**. Transfer case output devices are small motors that select the proper range by moving the internal transfer case linkage. Some motors operate through self-contained reduction gears. Some motors are direct drive types, while other motors are bidirectional.

The indicator and warning lights on the vehicle dashboard are also considered output devices. The lights tell the

driver the current transfer case range and warn of problems. The sequence of sensor inputs, ECM decisions and actions, and output device operation completes the control loop. Figure 18-19 shows a typical transfer case control loop.

Locking Hubs

Some vehicles use **locking hubs** to engage and disengage the front wheels from the front drive axles. Typical front locking hubs are shown in Figure 18-20. Although the operation of locking hubs is less complicated than other drive selection systems, they do have some disadvantages. For example, operating locking hubs requires the driver to get out of the vehicle, often in bad weather or in mud. Also, the front-wheel drive components in a locking hub system turn constantly, even when the front wheels are disengaged.

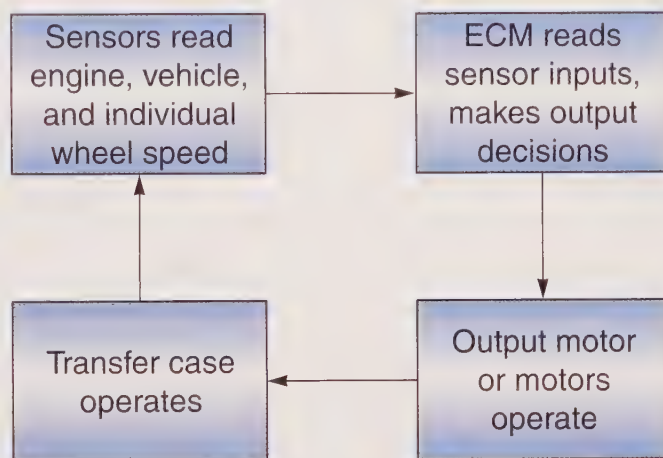


Figure 18-19. This control loop illustrates how the ECM determines the needed transfer case range and gear using speed inputs from the front and rear axles. The ECM may receive other inputs, such as engine speed and temperature, transmission gear, and whether the brakes are applied.

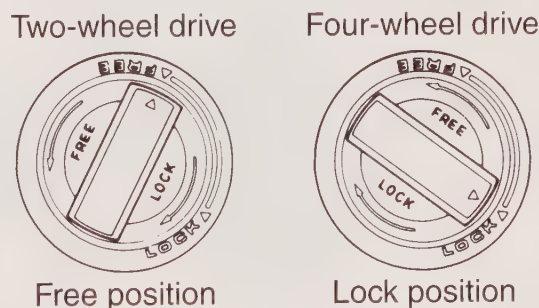


Figure 18-20. Many transfer cases are not equipped with any way to disengage the front-wheel drive components. In systems equipped with this type of transfer case, locking hubs must be used to disconnect the front wheels from the drive components. Locking hubs are often used even when the drive shaft or front axle can be disconnected from the remainder of the drive train. The hubs in these systems are unlocked to prevent the front wheels from turning the front drive components. (Ford)

Locking hubs are sometimes used on vehicles that have provisions for disengaging the front drive components. Unlocking the hubs in this type of system prevents the front wheels from driving the axles and the differential. This reduces wear on the front-drive parts. **Figure 18-21** shows an exploded view of the front locking hub mechanism. The splines of the hub are attached to the axle shaft

and are engaged by turning the recessed handle at the center of the hub. This moves the hub outward for engagement or inward for disengagement.

Some front locking hubs engage automatically. They are designed to release the front drive components whenever the transfer case is in the two-wheel drive position. The action of some of these hubs is similar to that of the one-way, or overrunning, clutch used in automatic transmissions. When the transfer case is in four-wheel drive, the engine is driving the front wheels. The one-way action of the hubs causes them to lock up to deliver power. When the engine slows down or the transfer case is taken out of four-wheel drive, the front wheels begin to drive the axles. This reverses the power flow through the hubs, causing them to unlock. The front drive parts stop moving to reduce wear and increase gas mileage.

Other self-locking hubs, such as the one shown in **Figure 18-22**, are engaged by moving the shift lever into the four-wheel drive position and disengaged by reversing the vehicle slightly after moving the shift lever into the two-wheel drive position.

Drive Shafts and Drive Axles

The drive shaft assemblies and drive axles used in four-wheel drive vehicles are identical to those used in two-wheel drive vehicles. Drive shaft assemblies are used to connect the transfer case to the front and rear differential units. Drive axles are used to connect the differential units to the drive wheels.

On some vehicles, the drive shafts are almost equal in length, **Figure 18-23A**. On other vehicles, the front drive shaft is shorter than the rear drive shaft. In some cases, a

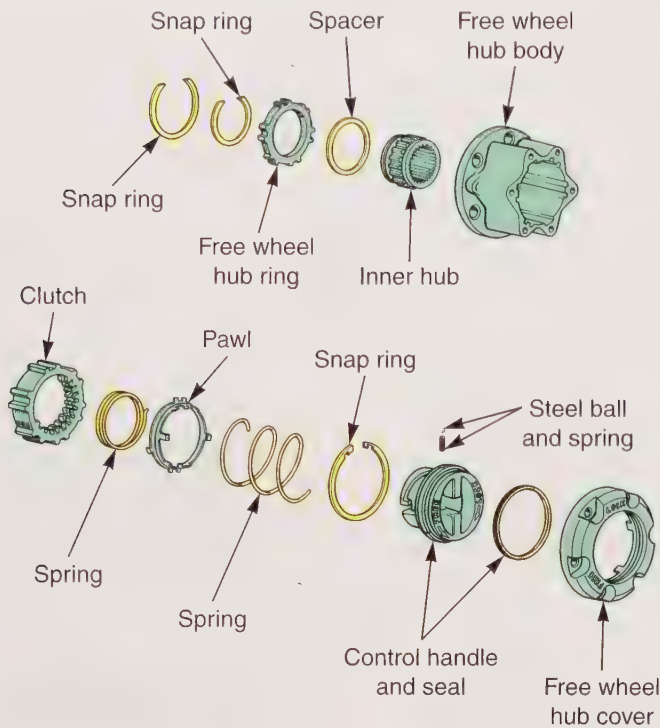


Figure 18-21. Exploded view of a front hub assembly. Note the engagement mechanism. When the splines on the axle, drive gear, and hub are engaged, the wheel is locked to the axle. When the splines are disengaged, the wheel is unlocked. (Ford)

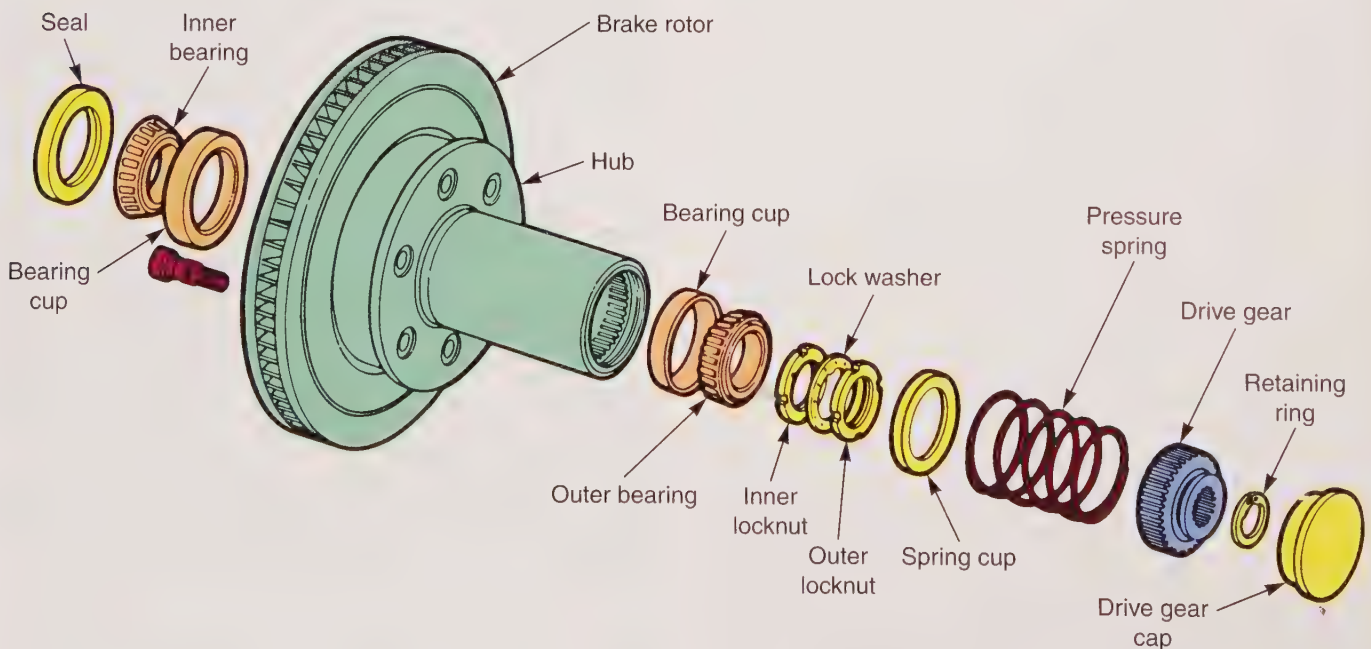


Figure 18-22. Study the parts of this automatic front locking hub. The locking mechanism in this type of hub may be operated by one-way clutch action or by reversing the vehicle after the transfer case is engaged. (Toyota)

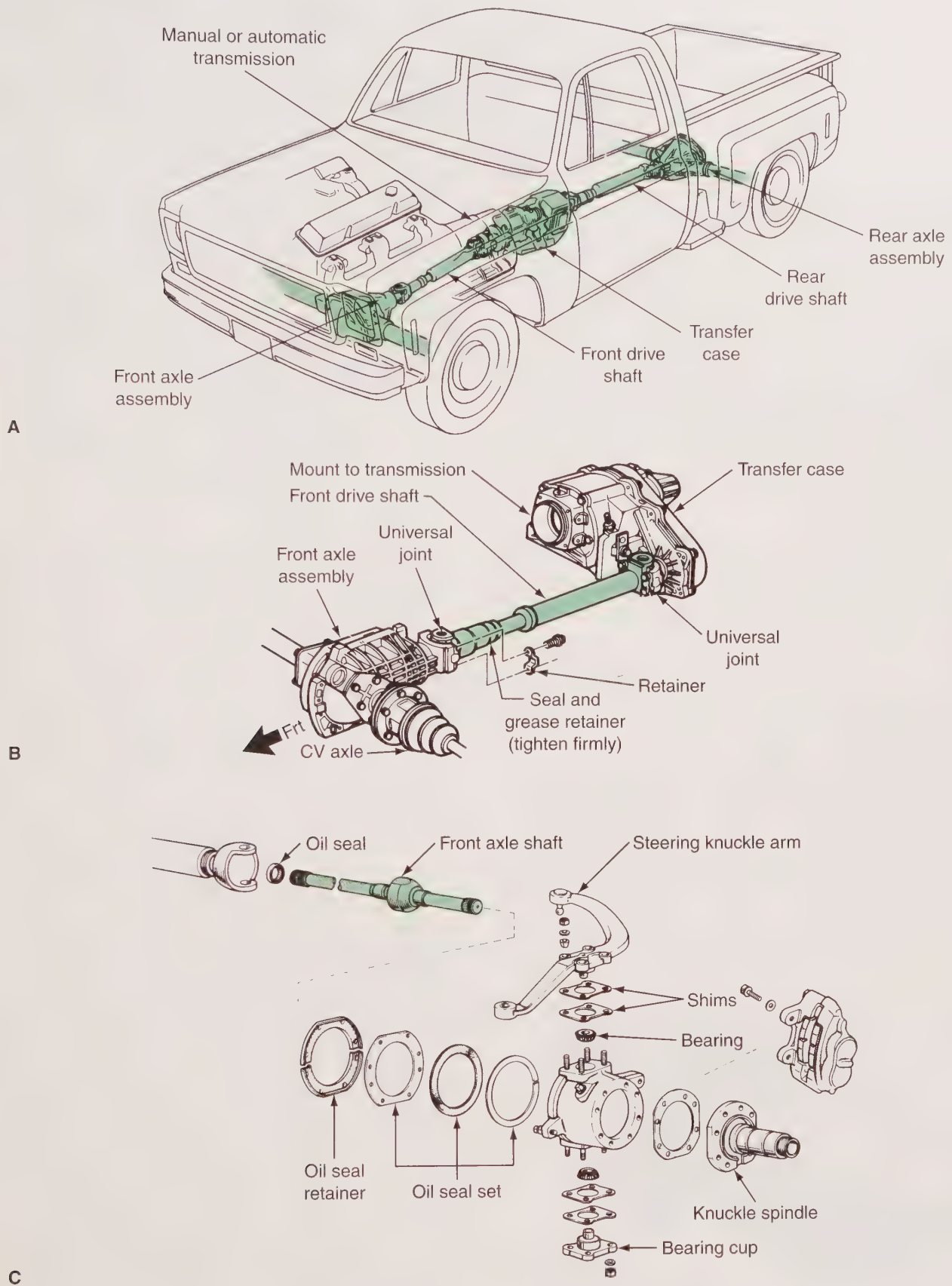


Figure 18-23. Note the various types of drive shafts used on four-wheel drive systems. A—The drive train of a longitudinal engine and transmission system includes two drive shafts with universal joints and slip yokes. B—The front drive shaft used with a longitudinal engine-transmission system is shown. The universal joints are attached to yokes at the transfer case and the front axle assembly. The shaft also has a slip yoke and grease fittings. C—The front axle shafts may be solid or independently sprung. The front shaft is equipped with a CV joint at the steering spindle. This allows the suspension to move as the wheels are turned. (General Motors)

front drive shaft is not needed. **Figure 18-23B** shows a front drive shaft assembly, which includes conventional U-joints to provide flexibility and a slip yoke to compensate for changes in length. The rear drive shaft assembly will also have a slip yoke and U-joints.

Solid axles are usually found on trucks with four-wheel drive systems. These shafts are identical to those used for the drive axles of rear-wheel drive vehicles. Constant-velocity axles (CV axles) are utilized on many four-wheel drive automobiles. These vehicles may have CV axles at the front and a solid axle at the rear, or they may have CV axles at all four wheels. **Figure 18-23C** shows one type of CV joint used with a front drive axle.

Other Four-Wheel Drive Parts

Various parts may be connected to the transfer case, including the four-wheel drive indicator light switch, shifter, body ground cable, and speedometer connector. See **Figure 18-24**.

The axle and differential assemblies used in four-wheel drive vehicles resemble the parts used in two-wheel drive vehicles. The ring and pinion gears are conventional hypoid-type gears. In many cases, the differentials used at the axles are not limited-slip models.

The steering system parts used in a four-wheel drive vehicle are also similar to those used in two-wheel drive vehicles. If the vehicle uses a front transaxle, parts will be identical to those used on the two-wheel drive version of the same vehicle (if available).

On vehicles equipped with a transmission originally designed for rear-wheel operation, the front spindle assemblies will be designed to allow the drive axles to pass through to the front hub. Other steering system parts will be similar to those used on two-wheel drive versions of the vehicle.

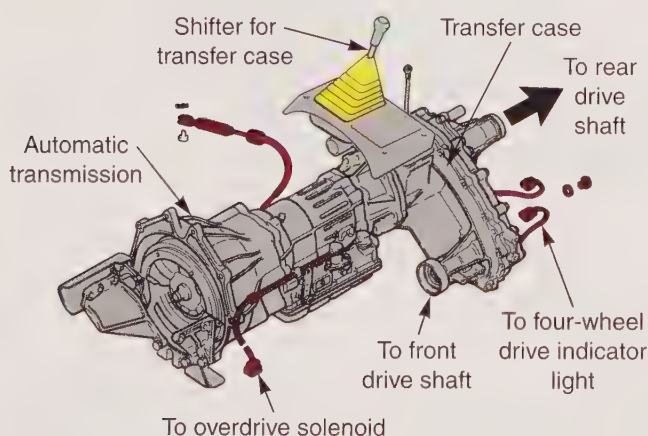


Figure 18-24. Note the external parts installed on this transfer case. (Chrysler)

Types of Automatic Four-Wheel Drive

There are two general types of automatic four-wheel drive. Both types have electronically controlled transfer cases that use a combination of driver commands and sensor inputs to automatically select between two- and four-wheel drive ranges, as discussed earlier in this chapter. One, called the **range and gear ratio control transfer case**, also selects high or low gear ratios in either range. This system is used on larger sport utility vehicles. The other, called the **range control only transfer case**, is used on light-duty vehicles to select between two- or four-wheel drive but has a single gear ratio. The two types are discussed below:

Range and Gear Ratio Control Transfer Case

The range and gear ratio control transfer case usually operates automatically. The driver can select some modes manually. The dashboard-mounted control panel allows the driver to select one of three manual ranges: two-wheel high gear, four-wheel high gear, and four-wheel low gear. There is also a Neutral position for towing. If the driver selects another range called four-wheel automatic, the ECM automatically selects two-wheel high, four-wheel high, or four-wheel low. This system also has a method of disconnecting the front drive axle in certain modes.

The transfer case, shown in cutaway form in **Figure 18-25**, contains the planetary gears, drive chain and sprockets, and shafts of a conventional transfer case. It also has a multiple plate clutch pack. Refer to the cutaway illustration in **Figure 18-25** as you read the following sections.

In two-wheel drive, the internally and externally splined clutch plates are close to each other but are not touching. When the plates are in this position, the clutch pack is released. The internally splined plates turn with the rear wheel output shaft, and the externally splined plates do not receive power. Since the drum and input chain drive sprocket are splined to the externally splined plates, they also do not receive power. Engine power flows through the transfer case output shaft to the rear wheels only.

When two-wheel drive is selected, the ECM energizes a motor. The motor moves the clutch fork that presses the clutch plates together. Pressing the clutch plates together causes them to act as a single unit, because of the friction between the faces of the internally and externally splined plates. When the plates are pressed together, the clutch pack is applied. Power is transferred from the internally splined plates to the externally splined plates. This causes the input chain drive sprocket to turn with the rear wheel output shaft. The input sprocket drives the chain and output sprocket. Engine power flows through the transfer case

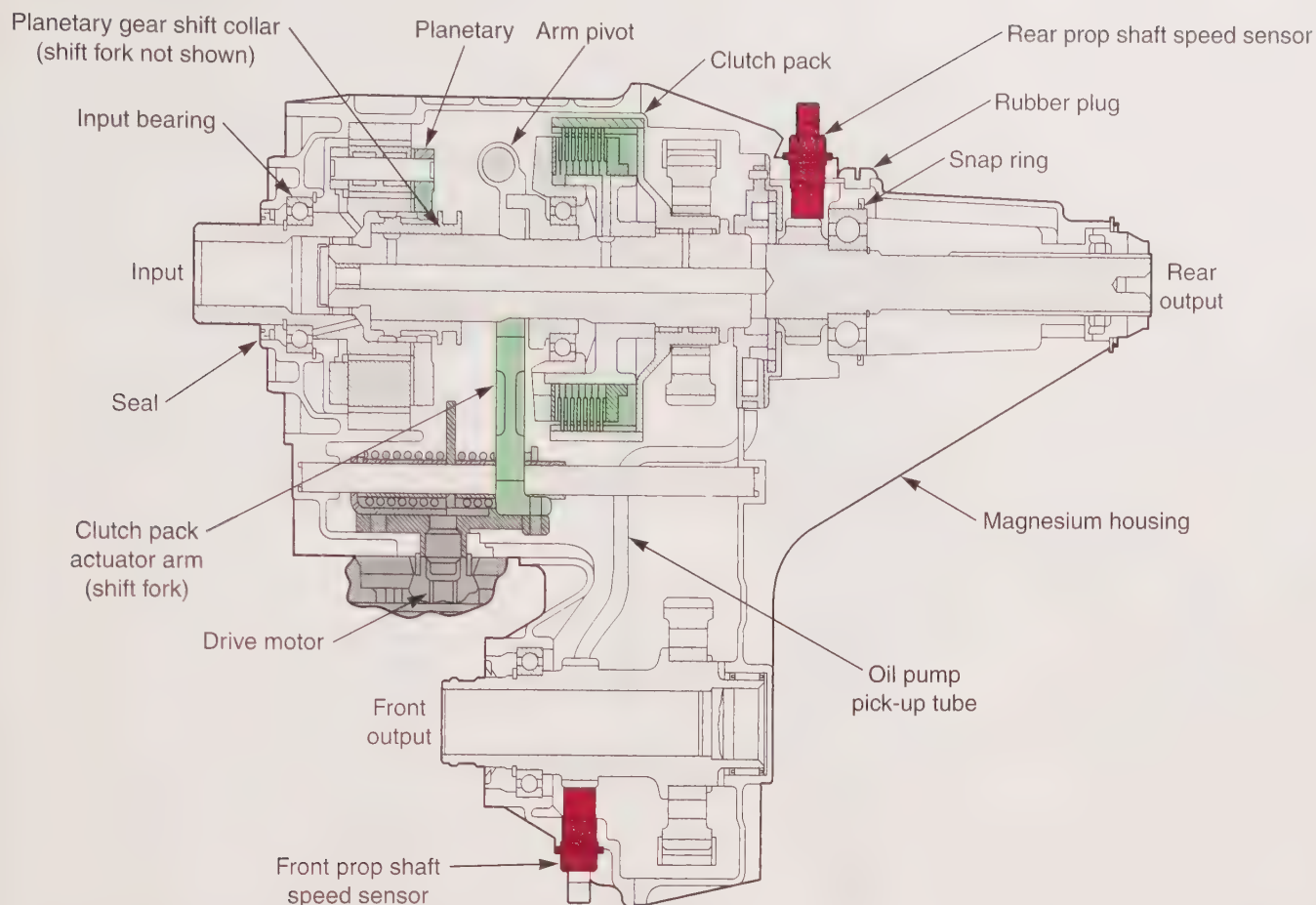


Figure 18-25. This cutaway view of an electronic transfer case shows the shift motor, shift fork, and clutch pack. The shift fork that controls the planetary gear is not shown. (General Motors)

output shaft, through the front drive shaft, and to the front wheels.

In this design, the control motor also controls the planetary gear application through another shift fork. Once four-wheel drive has been selected, the motor continues to run and moves the other shift fork. Movement of this shift fork causes the planetary gear to change the ratios between the transmission output shaft and the front and rear drive shafts. The exploded view in **Figure 18-26** illustrates the two shift forks used to control the clutch pack and the planetary gear. **Figure 18-27** is an exploded view of the internal components of an automatic transfer case with range and gear ratio controls. Note the clutch pack in addition to the other components. There is no need for a viscous clutch in this transfer case, since the electronic control system switches to four-wheel drive only when necessary. **Figure 18-28** is an electronic control schematic of this type of transfer case.

Range Control Only Transfer Case

The range control only transfer case is able to change between two- and four-wheel drive ranges, but has the same gear ratio in either range. It has a clutch pack that is manually applied by a motor and clutch fork, but no planetary gears. The clutch pack operates in the same manner as the clutch pack in the range and gear ratio control transfer case. On this

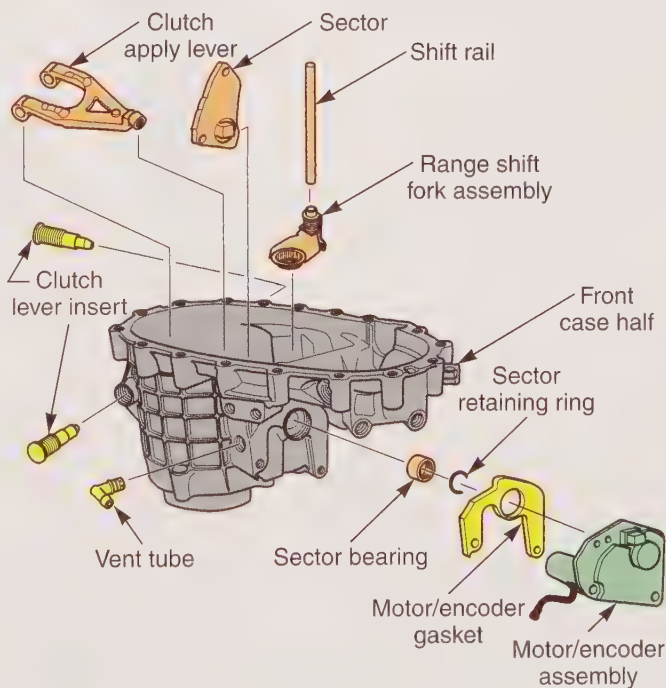


Figure 18-26. This exploded view of the case shows the dual shift forks used to select the range and gear ratio. Both forks pivot on internal shafts and are controlled by the same motor. (General Motors)

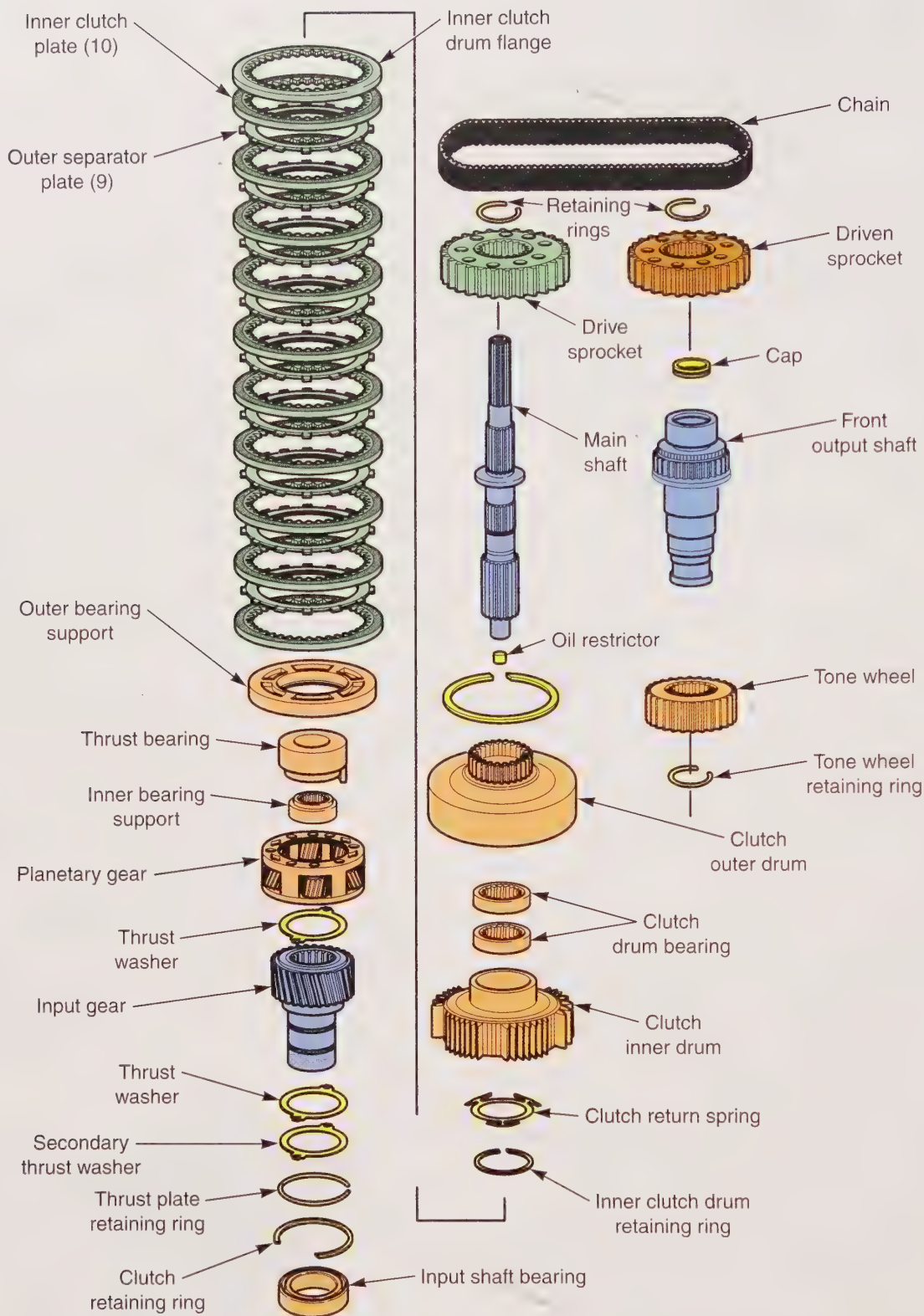


Figure 18-27. The clutch pack and planetary gearset can be seen in this exploded view of the transfer case drive parts. The sprockets and chain are similar to those used on mechanically operated transfer cases. (General Motors)

system, the front axle is always engaged to the transfer case. The ECM operates the control motor based on inputs from speed sensors. One sensor measures the speed of the rear output shaft. The other sensor measures the speed of the front output shaft. The ECM processes these inputs, as well as other

information, and issues output commands. This system has no driver inputs, although the driver indirectly affects transfer case operation by selection of vehicle speed and throttle position.

Figure 18-29 is an exploded view of the internal parts of a range control only transfer case. Note that unlike the

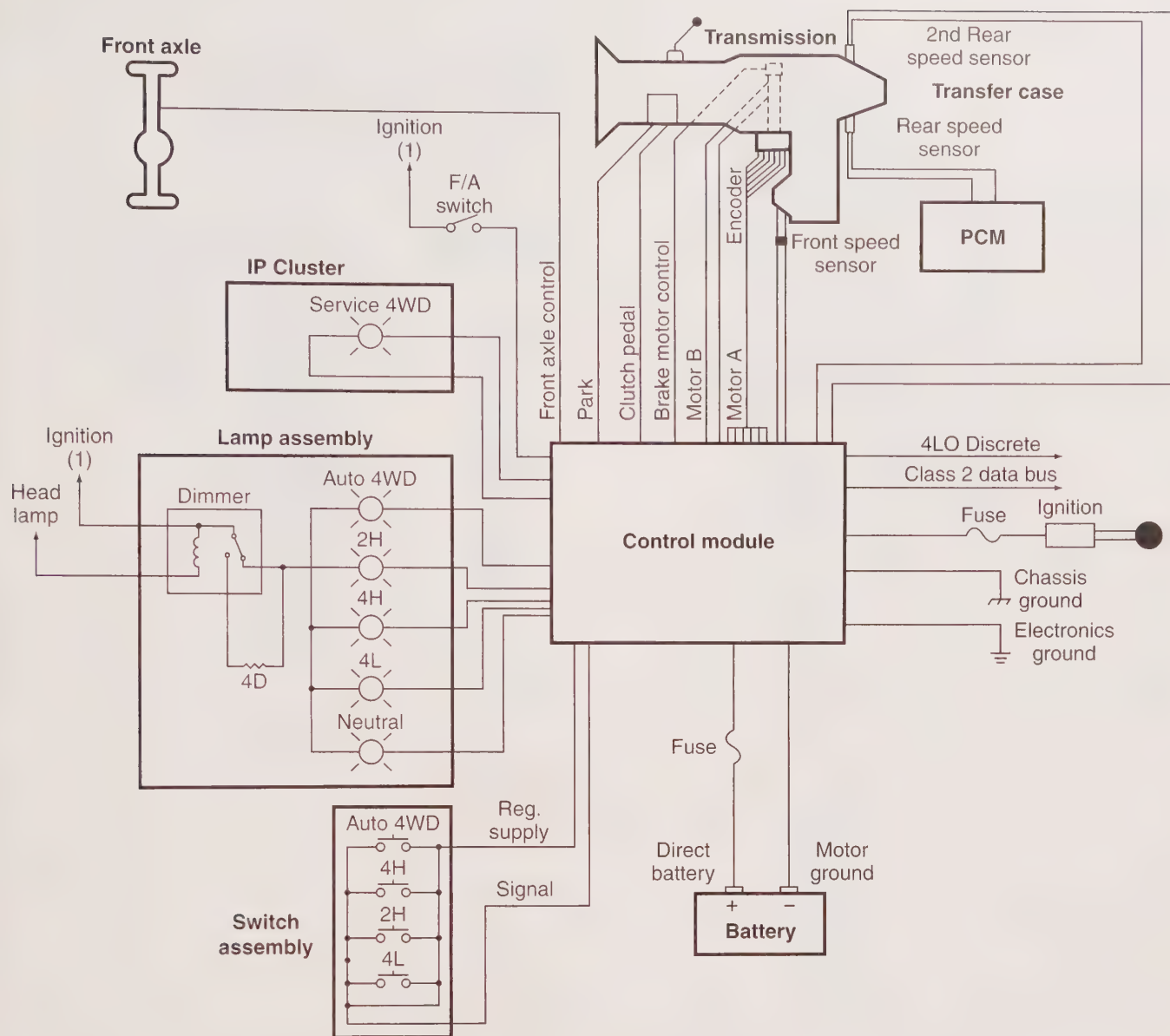


Figure 18-28. This illustration is a schematic of an electronic transfer case control system. It has provisions for manual selection of two- or four-wheel drive range and gear ratios. The transfer case ECM is separate from the power train control module (PCM). The control system also operates the engagement motor on the front drive axle.

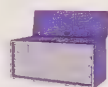
unit in **Figure 18-27**, this transfer case has no planetary gears. Since the transfer case has only one speed, planetary gears are not needed. The transfer case has no viscous clutch since the clutch pack controls power flow to the front wheels. The exploded view of the case in **Figure 18-30** shows the single shift fork used to apply the clutch pack. The schematic in **Figure 18-31** shows the control system of a typical range control only transfer case.

Transfer Case Power Flow

Because they contain many of the same parts, the transfer case can be thought of as a compact transmission. However, the transfer case parts are usually arranged for a

lateral (sideways) power flow. The conventional transmission is arranged for linear (front-to-back) power flow.

Many vehicles with full-time four-wheel drive employ a single-speed transfer case, which has only one power flow path. Part-time transfer cases used in off-road vehicles usually have at least three drive combinations: two-wheel drive, high-gear position; four-wheel drive, high-gear position; and four-wheel drive, low-gear position.



Note: On four-wheel drives used on some vehicles, the front-wheel drive is disconnected at the front axle and the transfer case is in four-wheel drive at all times. These transfer cases may have high and low ranges.

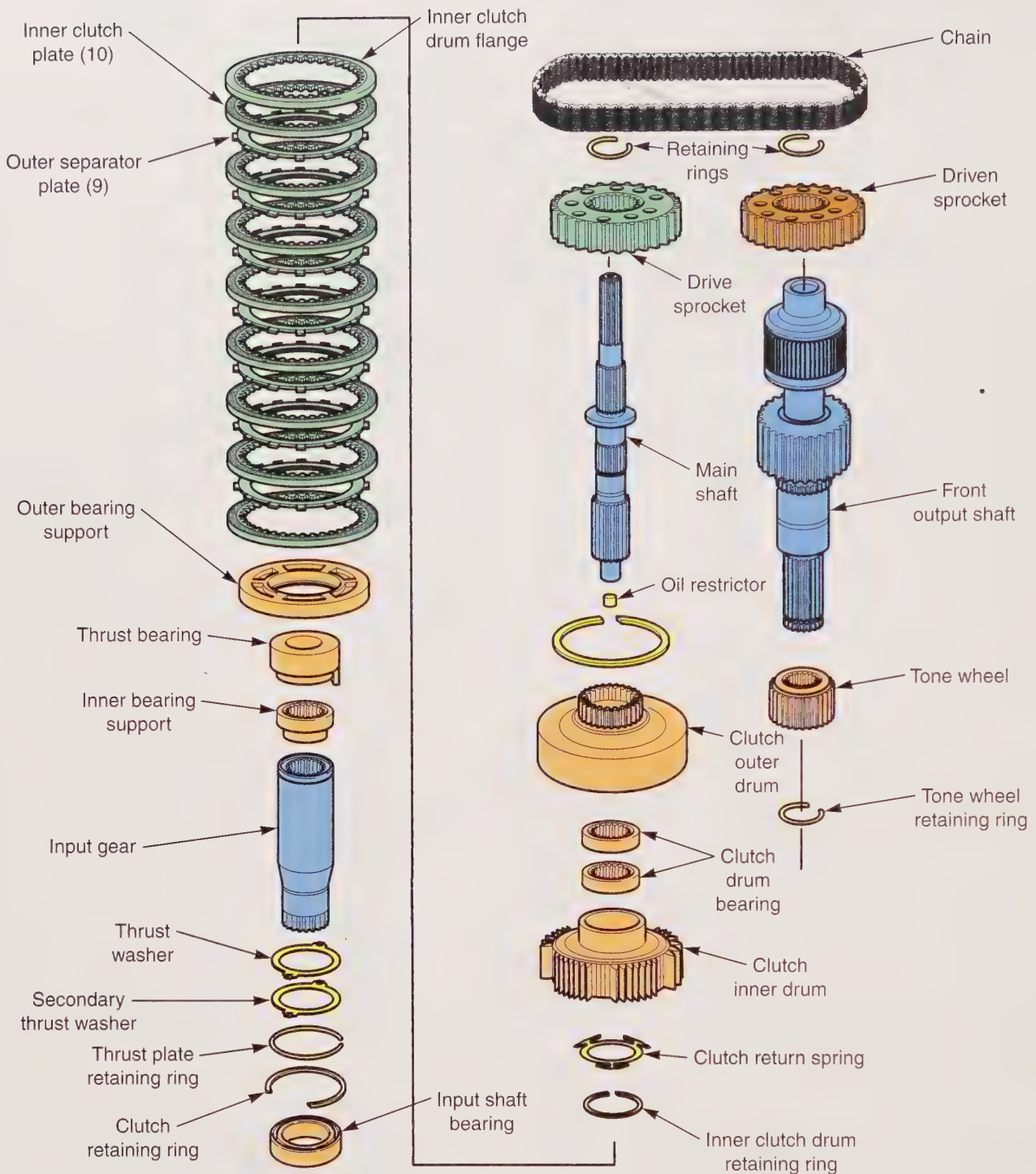


Figure 18-29. This exploded view of the internal transfer case drive parts shows the clutch pack. The input gear replaces the planetary gearset. The clutch pack is always driven at transmission output shaft speed. (General Motors)

Chain Drive Transfer Case Power Flow

Almost all modern four-wheel drive systems use a chain drive transfer case. Chain drives are used in combination with many other transfer case components, such as planetary gears, differential assemblies, viscous clutches, and electronically controlled clutch packs. Chain drive transfer cases are controlled manually by the driver or by various pneumatic, hydraulic, electrical, and/or electronic devices.

In **Figure 18-32**, a chain drive transfer case is shown in a cutaway view. In this simplified drawing, only the major internal parts are shown. Types of transfer case drive and control components vary greatly between manufacturers. Always consult the appropriate service literature for the exact components used in any transfer case. Most modern chain drive transfer cases have such components as shift forks, clutch packs, viscous couplings, and various electrical and electronic devices. The gear ratio selector

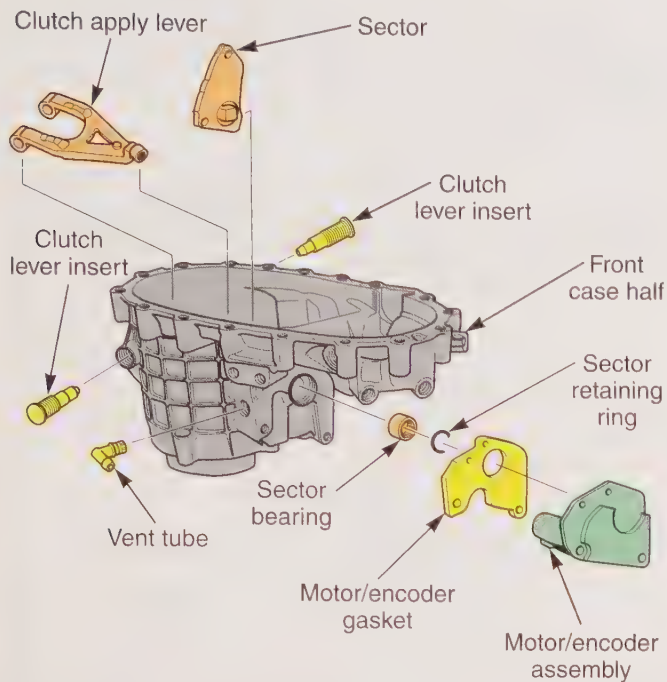


Figure 18-30. This exploded view of the case shows the single shift fork used to select two- or four-wheel drive. The sector is rotated by the motor and moves the shift fork. (General Motors)

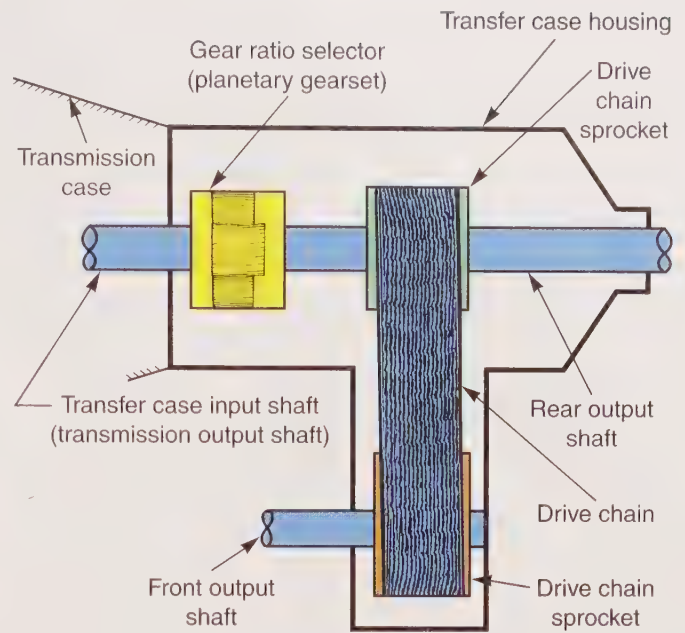


Figure 18-32. Cutaway view of transfer case with chain drive. For clarity, gear selector devices and details of the planetary gearset are not shown. Devices not used on all transfer cases, such as viscous couplings and clutch packs, are also not shown. On some vehicles, the gear ratio is fixed and the planetary gear ratio selector is not used. On other vehicles, driver-selected gears are used instead of a planetary gearset.

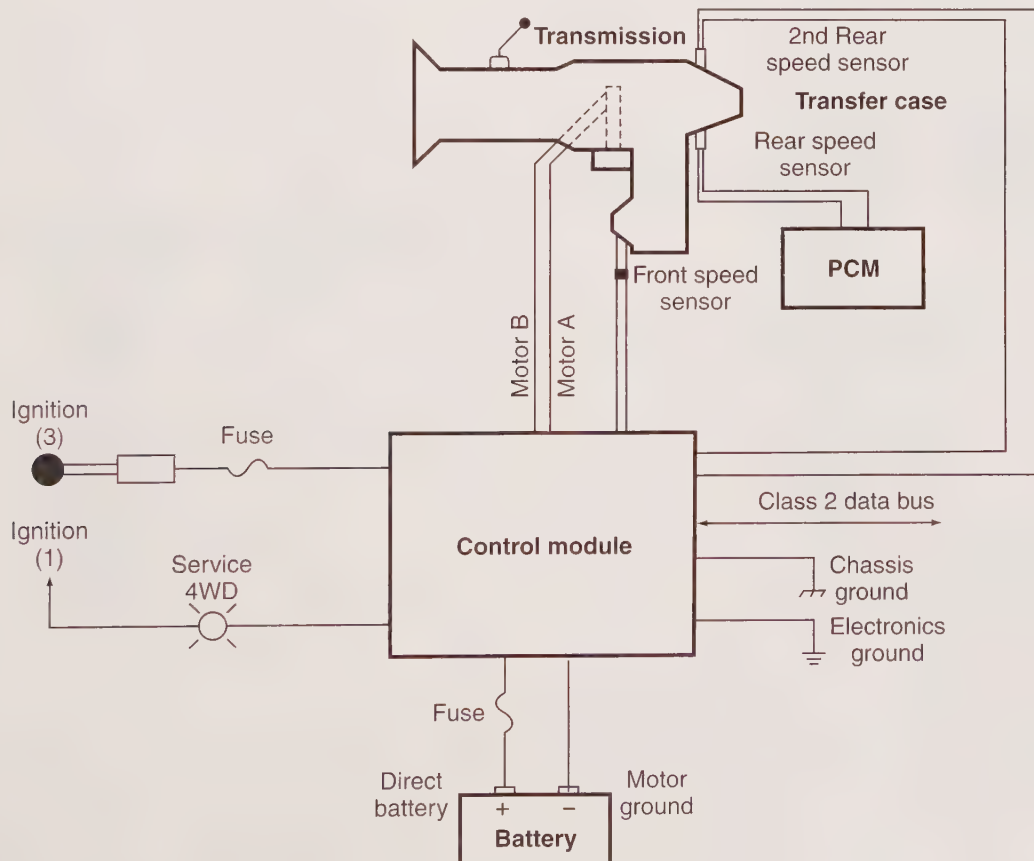
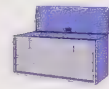


Figure 18-31. This schematic shows how the ECM receives inputs and operates the transfer case shift fork. This system is much simpler than the one shown in Figure 18-28. The control system has provisions for manual selection of two- or four-wheel drive range.

will be called a planetary gearset in this section, since all modern chain drives use a planetary unit for changing ratios. Transfer cases used on some smaller vehicles have no provision for a low gear, and there is no planetary gearset.

In two-wheel drive and high gear, power flows into the transfer case from the transmission output shaft and through the planetary gearset. The planetary gearset is in the high position and turns as a unit. This creates a one-to-one ratio through the gearset. From the planetary gearset, power flows through the output shaft to the rear axle. The output shaft rotates inside the upper drive chain sprocket but does not transfer power to the sprocket. See **Figure 18-33**.

In **Figure 18-34**, the transfer case has been shifted into four-wheel drive and high gear. Power continues to flow from the transmission output shaft through the planetary gearset at a one-to-one ratio. At this point, the gear selection mechanism connects the output shaft to the upper drive chain sprocket. Engine power continues to flow through the output shaft to the rear axle. Power also flows through the upper drive train sprocket, through the drive chain, and into the lower sprocket. The lower sprocket is splined to the front output shaft, so power flows into the front output shaft to the front axle. Power is split and drives both the front and rear axles.



Note: The following paragraph does not apply if the transfer case has no provision for low gear.

If the driver selects four-wheel drive and low gear, power flows from the transmission output shaft into the planetary gearset. The planetary gearset has been shifted into the low gear position and the action of the gears reduces speed to a lower ratio, as shown in **Figure 18-35**. A lower ratio causes the input speed to be reduced while increasing the amount of torque delivered. Power then flows to the rear output shaft, to the upper drive chain sprocket, chain, and lower drive chain sprocket, and out to the front axle.

Gear Drive Transfer Case Power Flow

Gear drive transfer cases are less common than chain drives. Most older four-wheel drive vehicles had gear drive transfer cases. Gear drives are often used on newer imported automobiles with full-time four-wheel drive, and four-wheel drive vehicles with transverse engines and transaxles.

Figure 18-36 shows power flow through one kind of gear drive transfer case. This type of transfer case can provide both two- and four-wheel drive, with no need to disengage the front-wheel drive at the front axle. The central idler shaft is used to ensure both output shafts rotate in the

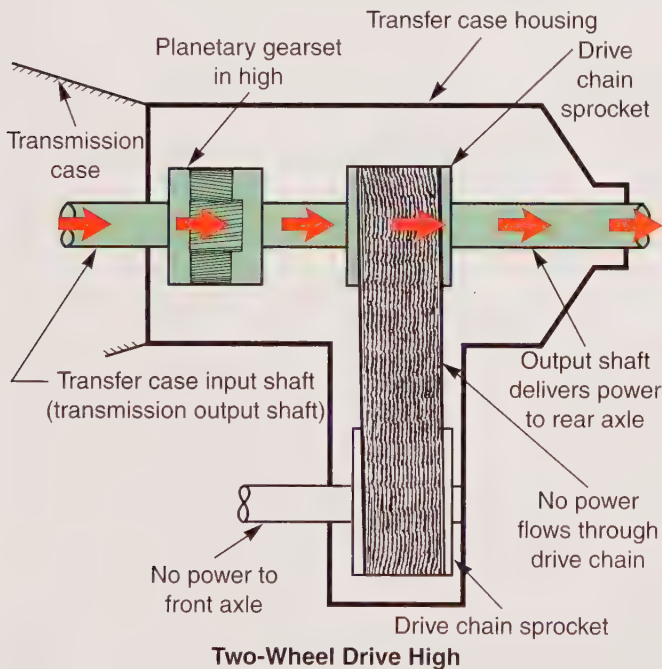


Figure 18-33. The transfer case is in two-wheel drive and high gear. Power flows directly through the planetary gearset at a one-to-one ratio. From the gear ratio selector, planetary gearset power flows through the output shaft to the rear axle. The output shaft rotates inside the upper drive chain sprocket but does not transfer power to the sprocket.

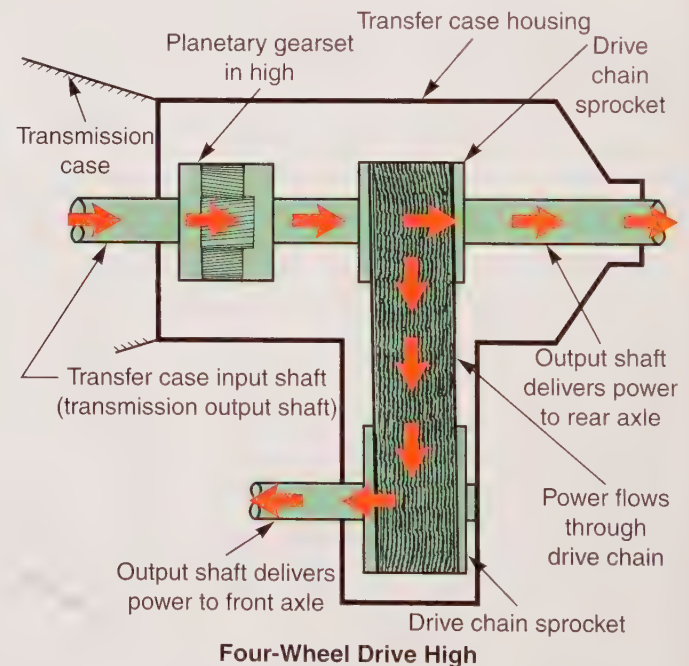
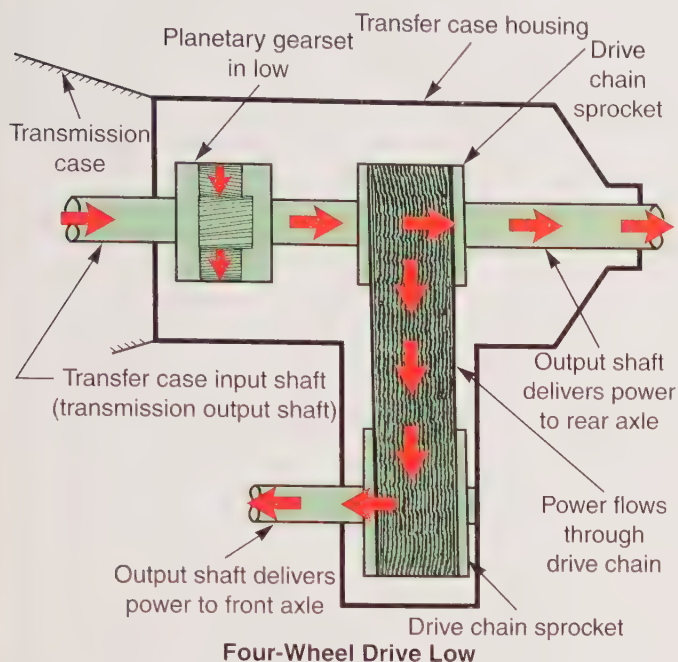


Figure 18-34. The transfer case is in four-wheel drive and high gear. Power flows directly through the planetary gearset and the output shaft to the rear axle. The output shaft is connected to the upper drive chain sprocket. Power flows through the upper drive train sprocket, through the chain, and into the lower drive chain sprocket. The lower drive train sprocket is splined to the front output shaft, and power flows into the front output shaft to the front axle.



Four-Wheel Drive Low

Figure 18-35. The transfer case is in four-wheel drive and low gear. Power flows into the planetary gearset, where the action of the gears reduces speed and increases torque. Power then flows through the output shaft; to the rear axle; to the upper drive chain sprocket, chain, and lower drive chain sprocket; and out to the front axle.

same direction. In **Figure 18-36A**, the transfer case is in the two-wheel drive position. Power enters the transfer case from the transmission and turns the rear drive shaft assembly. The central idler shaft and front drive gear are turning, but the top sliding clutch sleeve is not engaged. No power is delivered to the front wheels. In **Figure 18-36B**, the top sliding clutch sleeve has been engaged, and power is delivered to both the front and rear drive shaft assemblies. This is four-wheel drive, high gear.

To obtain four-wheel drive low gear, both sliding clutch sleeves are moved to the right and their external gear teeth engage the right side gear on the central idler shaft, **Figure 18-36C**. Power flows from the input gear, to the left side of the idler gear, to the right side of the idler gear, and to the two clutch sleeves and their output shafts. The right side idler gear is smaller than the two output shaft gears. Therefore, the output shaft gears turn more slowly than the idler gear, and torque is multiplied through the gearset. This is four-wheel drive, low gear.

Another way to obtain low and high gear ratios in a gear drive transfer case is shown in **Figure 18-37**. The input gear is splined to the transfer case input shaft and turns with the shaft. The input gear can slide back and forth on the input shaft to engage either the low range gear on the idler gear assembly or the rear wheel output gear. In low range, the input gear meshes with the low range gear on the idler gear assembly, **Figure 18-37A**. Power flows through the input gear and idler gear assembly to turn the front and rear output gears.

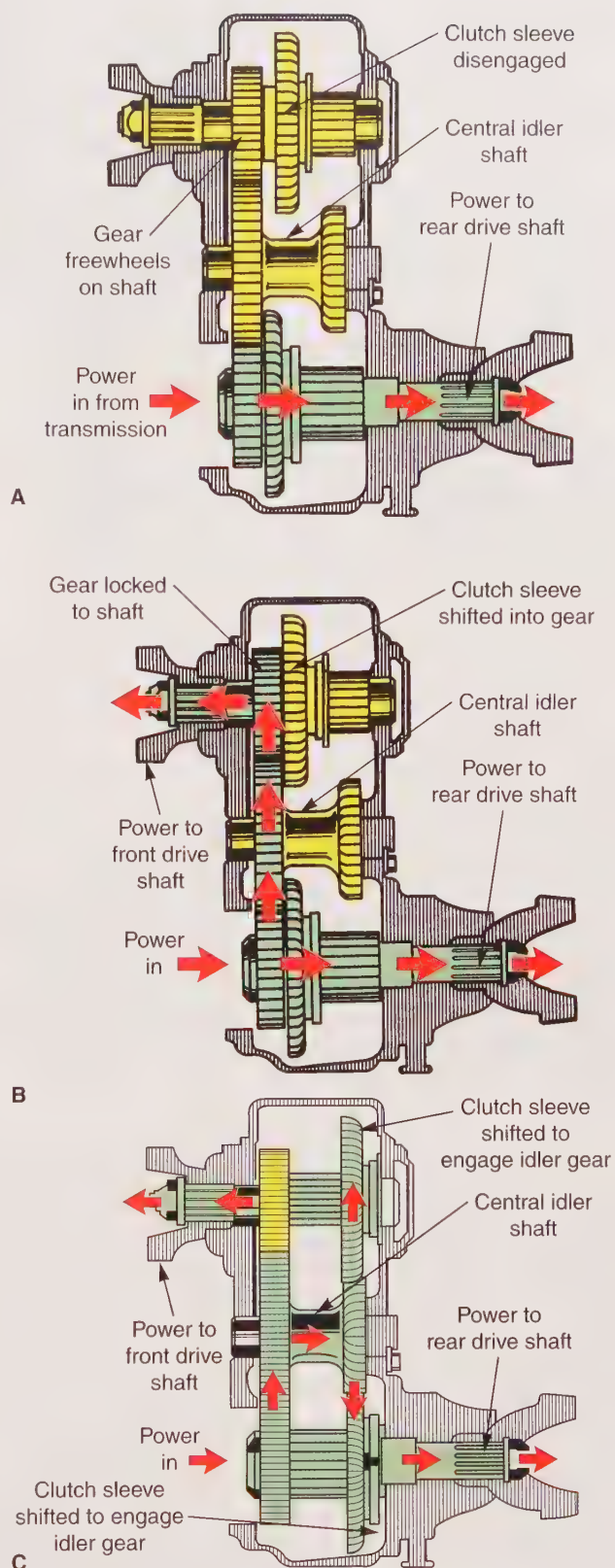


Figure 18-36. The arrows in this figure show transfer case power flow in two- and four-wheel drive positions. A—In two-wheel drive, power flows through the bottom gear of the transfer case to drive only the rear axle. B—In four-wheel drive high gear, power flows through the bottom gear, center idler gear, and top gear to drive both axles. The idler gear ensures that the top and bottom shafts turn in the same direction. C—In four-wheel drive low gear, power flows from the input gear, to the left side of the idler gear, to the right side of the idler gear, and to the two clutch sleeves and their output shafts. (Chrysler)

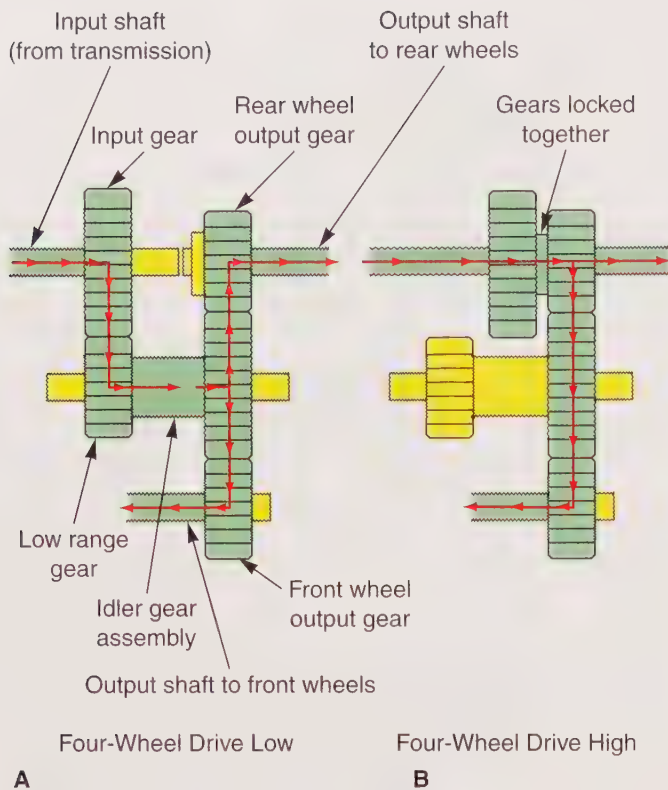


Figure 18-37. This figure shows how gears can be used to obtain high and low ranges in a transfer case. The input gear is splined to the input shaft from the transmission and turns with the shaft. **A**—In low range, the input gear is meshed with the low range gear on the idler gear assembly. Power flows through the input gear and idler gear assembly to the front and rear output gears. **B**—In high range, the input gear and rear wheel output gear are locked together. Power flows directly from the gear to the rear output gear, and from the rear output gear through the idler gear to the front output gear.

To obtain high range, the input gear slides rearward and engages teeth on the inside of the rear wheel output gear, **Figure 18-37B**. This locks the input and rear wheel output gears together. Power flows directly from the input gear to the rear output gear, and from the rear output gear through the idler gear to the front output gear. Notice that this type of transfer case has only two ranges: four-wheel low and four-wheel high. To obtain two-wheel drive, the front drive axles are disconnected from the front drive shaft. Disconnection is done by vacuum or mechanical devices or manually operated locking hubs. These devices were explained earlier in this chapter. Notice that the gear drives in **Figure 18-36** and **Figure 18-37** use a central idler gear to obtain both high and low ranges.

Summary

The main purpose of a four-wheel drive system is to increase traction by dividing engine power among all four wheels. There are two major four-wheel drive systems: the part-time system, which permits the operator to choose between two-wheel drive and four-wheel drive, and the full-time system, which drives all of the wheels whenever the vehicle is moving. The part-time system is used on most off-road vehicles. The full-time system is designed primarily for on-road use.

The transfer case is the heart of the four-wheel drive system. The transfer case housing supports and protects the moving parts and acts as a reservoir for lubricant. The design of the transfer case housing varies with the size and complexity of its internal parts and the type of transmission to which it is attached.

Some transfer cases have an oil pump to provide lubricating oil at low pressures. The front and rear drive shafts extend from the transfer case to the axle assemblies.

To compensate for speed differences between the front and rear axles, many four-wheel drive systems are equipped with a central differential or a viscous coupling. The central differential, which operates in the same manner as a rear axle differential, compensates for axle speed variations.

To prevent wheel spin on slippery surfaces, locking or limited-slip differentials are often used. In some cases, viscous couplings are used to prevent slippage by the action of the thick fluid between drive plates and driven plates. These couplings can also compensate for speed variations. Some vehicles have both a differential and a viscous coupling. Some transfer cases have a multiple plate clutch pack. This consists of a series of clutches with alternating internal and external splines. Applying and releasing this clutch pack places the transfer case in either two- or four-wheel drive.

Most full-time four-wheel drive systems do not have a shift mechanism. Transfer cases that require operator gear changes are shifted by manual linkage, vacuum diaphragms, electric solenoids, or motors. The transfer case shift lever is usually mounted near the transmission gear-shift lever.

Electronic transfer cases eliminate the need for manual range and gear selection. Electronic transfer cases use an on-board computer called an ECM, PCM, or TCCM. On some vehicles the engine and drive train computer operates the transfer case. On other vehicles, a separate computer is used. In addition to the computer, electronic transfer cases have speed sensors and output motors. The

computer, sensors, and motors form a control loop. The control loop determines which gear and range should be selected for any set of operating conditions. Some electronic transfer cases are fully controlled by the driver. The computer acts only to prevent improper driver selections. Most electronic transfer cases are completely automatic, or a combination of automatic selections and manual driver controls.

Some vehicles have locking hubs to engage and disengage the front wheels. Locking hubs are usually used when the transfer case does not have any provision for unlocking the front wheels. Locking hubs are sometimes used in combination with the transfer case to ensure the front drive parts are not driven by the engine or the road. Although locking hubs are usually manually operated, some hubs lock and unlock automatically.

The drive shafts used in four-wheel drive systems are identical to those used in two-wheel drive systems. They may be equipped with universal joints, which provide flexibility, and a slip yoke, which compensates for variations in length. Axle shafts may be solid or flexible, depending on the vehicle design and whether they are used on the front or rear axles. Flexible shafts usually have CV joints at their outboard ends.

There are two general types of automatic four-wheel drive: the range and gear ratio control transfer case and the range control only transfer case. Both types have electronically controlled transfer cases that use a combination of driver commands and sensor inputs to automatically select between two- and four-wheel drive ranges. The range and gear ratio control transfer case also selects high or low gear ratios in either range. The range control only transfer case, however, has a single gear ratio.

Power flow through a transfer case varies according to the design of the unit. Transfer case power flow may be through gears or a drive chain and sprockets. Chain drive transfer cases are common, and power flow depends on whether or not the input sprocket is locked to the rear output shaft. Helical gear transfer cases will have a central idler gear to ensure both output shafts are driven in the same direction. Planetary gear transfer cases usually operate in combination with a drive chain.

Review Questions—Chapter 18

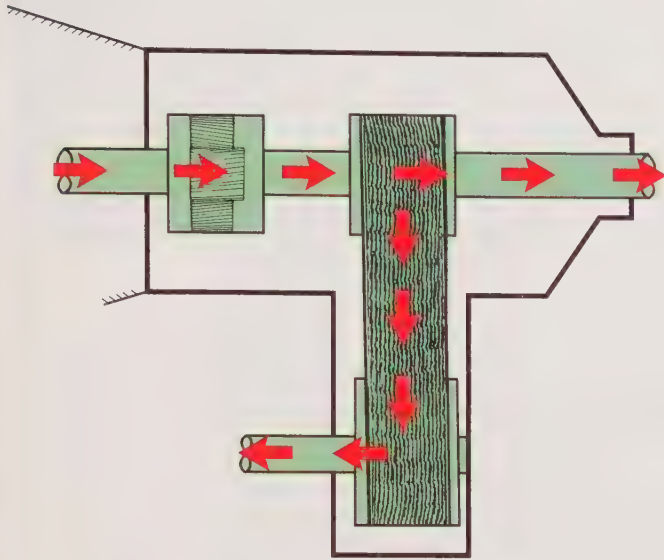
Answer the following questions using the information provided in this chapter.

1. Explain the difference between part-time four-wheel drive systems and full-time four-wheel drive systems.
2. List and explain the basic components of a typical four-wheel drive system.
3. The transfer case housing holds and aligns _____, _____, _____, and other components.
4. What is the purpose of a viscous coupling?
5. The central differential compensates for changes in speed as the _____ gears walk around the _____ gears.
6. How does a viscous coupling work?
7. Vehicles with electronic transfer cases use a(n) _____ to select transfer case ranges.
 - (A) push-button
 - (B) on-board computer
 - (C) locking hub
 - (D) shift lever
8. Each of the following is part of a control loop *except*:
 - (A) ECM decisions.
 - (B) output device operations.
 - (C) sensor inputs.
 - (D) battery charge input.
9. Explain power flow through a chaindrive transfer case in the two-wheel drive, high-gear position.
10. Sketch the power flow through a typical chaindrive transfer case in the four-wheel drive, low-gear position.

ASE-Type Questions—Chapter 18

1. Each of the following is a major type of four-wheel drive system *except*:
 - (A) full-time four-wheel drive.
 - (B) all-wheel drive.
 - (C) part-time four-wheel drive.
 - (D) 4 × 4 drive.
2. The transfer case splits power between _____.
 - (A) front and rear drive chains
 - (B) a viscous coupling
 - (C) front and rear wheels
 - (D) front and rear differentials
3. A transfer case housing serves, in part, as a reservoir for lubricating oil. Technician A says that gaskets are used at case halves and between the case and transmission to prevent oil leaks. Technician B says that the front and rear output yokes have seals to prevent oil loss. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
4. Most modern transfer cases use a chain and sprockets in combination with each of the following as drive mechanisms *except*:
 - (A) spur gears.
 - (B) helical gears.
 - (C) planetary gears.
 - (D) worm gears.
5. Technician A says that a viscous coupling is designed to compensate for differences in front and rear wheel speeds. Technician B says that a central differential is designed to compensate for differences in front and rear wheel speeds. Who is right?
 - A) A only.
 - B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
6. Each of the following parts may be connected to the transfer case *except*:
 - (A) a shifter.
 - (B) locking hubs.
 - (C) a body ground cable.
 - (D) a speedometer connector.
7. Part-time transfer cases used in off-road vehicles usually have each of the following drive combinations *except*:
 - (A) two-wheel drive, low-gear position.
 - (B) two-wheel drive, high-gear position.
 - (C) four-wheel drive, low-gear position.
 - (D) four-wheel drive, high-gear position.
8. Technician A says that the main purpose of a four-wheel drive system is to increase traction. Technician B says that the components required by four-wheel drive vehicles also help to improve gas mileage over the average two-wheel drive vehicle. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
9. Which of the following parts would *not* be installed on an electronic transfer case?
 - (A) ECM (computer).
 - (B) Rear output shaft speed sensor.
 - (C) Front output shaft speed sensor.
 - (D) Shift fork motor.
10. A hydraulic locking transfer case uses hydraulic pressure developed by _____.
 - (A) an electric motor installed in the transfer case
 - (B) an electric motor installed on the frame
 - (C) the power steering pump
 - (D) relative movement between the front and rear axle shafts
11. Each of the following statements about electronic transfer case speed sensors is true *except*:
 - (A) the speed sensor consists of a small wire coil surrounding a permanent magnet.
 - (B) a toothed wheel on the rotating shaft generates alternating current (AC) in the wire coil.
 - (C) higher speeds reduce the frequency of the AC signal.
 - (D) the ECM (computer) reads the change in signal frequency as shaft speed.

12. Electronic transfer cases are being discussed. Technician A says that the shift fork motor is an output device. Technician B says that the dashboard range indicator light is an output device. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.



13. The power flow through a chain drive transfer case is shown in the previous illustration. In what gear is the transfer case?
- (A) two-wheel high gear.
 - (B) four-wheel high gear.
 - (C) two-wheel low gear.
 - (D) four-wheel low gear.

14. Depending on the manufacturer, the front axle shift fork of a four-wheel drive vehicle may be operated by any of the following *except*:
- (A) electric solenoids.
 - (B) manual linkage.
 - (C) vacuum motors.
 - (D) hydraulic pistons.
15. Technician A says that on some electronic transfer cases the clutch pack is applied by motor-operated shift forks. Technician B says that on some hydraulic locking transfer cases the clutch pack is applied by centrifugal force. Who is right?
- (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.



Manual selector for two- and four-wheel drive ranges. (Ford)



Chapter 19

Four-Wheel Drive Problems, Troubleshooting, and Service

After studying this chapter, you will be able to:

- ☐ Diagnose transfer case mechanical and electronic problems.
- ☐ Remove a transfer case from a vehicle.
- ☐ Disassemble a transfer case.
- ☐ Inspect transfer case parts for wear or damage.
- ☐ Describe the parts typically replaced during a transfer case overhaul.
- ☐ Reassemble and install a transfer case.
- ☐ Disassemble, service, and reassemble a locking hub.

Technical Terms

Transfer case shudder

Pattern failure

Fault designator

Flash programming

Direct programming

Indirect programming

Programming device

Remote programming

Skid plate

Relearn procedure

Introduction

As a drive train technician, you must be able to service the transfer case and other components in a modern four-wheel drive system. This chapter summarizes the diagnostic and repair techniques used when servicing four-wheel drive vehicles. It draws on the material presented in previous chapters, such as information on manual transmissions and rear axle assemblies. If necessary, return to the appropriate chapters and review the material as needed. Drive train problems commonly encountered in four-wheel drive systems are illustrated in **Figure 19-1**.

Transfer Case Problems and Troubleshooting

Although it is relatively small, the transfer case can develop problems that affect the entire drive train. Accurately determining the source of a problem is the first step in repairing a transfer case. **Figure 19-2** shows some of the problems that can develop in a typical chain drive transfer case. **Figure 19-3** shows common problems in a typical gear drive transfer case.

Lubricant Leakage

Lubricant leakage in a transfer case is a loss of lubricating fluid from the housing, gaskets, or seals. Leaks may be noticed as oil drips on the pavement. Always begin troubleshooting an oil leak by making sure the leak is from the transfer case. Engine oil, transmission fluid, or power steering fluid can be mistaken for transfer case lubricant. As a vehicle is driven, oil leaking from the front components is sometimes blown onto the rear components. This makes it difficult to determine the origin of the leak.

One way to verify a transfer case leak is to check the oil level in the case. In most transfer cases, the oil level is correct if the oil just wets the bottom of the fill plug threads, **Figure 19-4**. If the oil level is normal, the leak is probably from some other part of the vehicle. If the oil level is low, there is generally a leak somewhere in the transfer case. If the oil level is too high, overfilling may be the cause of the leak. Overfilling may cause oil to be forced out of a seal or out through the case vent.

When looking for a transfer case leak, remember that oil will drip downward and is often blown to the rear of the vehicle. Look for leaks from loose or broken bearing retainers or from retainer gaskets. Check the seals in the area where the drive shaft yokes enter the transfer case. Leaks may also originate from loose case housing bolts and defective housing gaskets. Check for leaks from the drain and fill plugs and from bolts at the bottom of the transfer case. Some bolts must be installed with a thread sealant to prevent leaks.

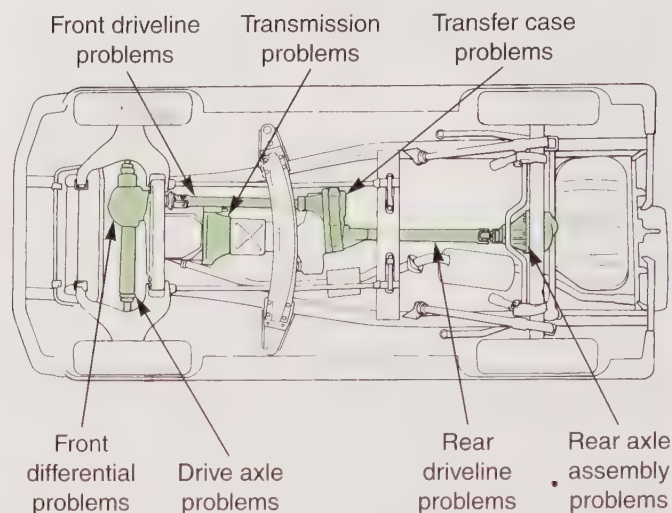


Figure 19-1. Various problems can occur in a four-wheel drive system. The transfer case, drive shafts, differentials, and locking hubs can all be sources of trouble. Be sure to pinpoint the problem before beginning repairs. (Chrysler)

Improper Engagement

When a transfer case fails to engage properly, no power will be transmitted to one or to both sets of wheels. However, a transfer case rarely fails to drive at least one set of wheels. If the vehicle will not move in any transfer case mode, the problem is usually caused by a defective transmission or by a binding axle. If the transfer case fails in only one gear, the problem may be caused by defective internal parts or linkage.

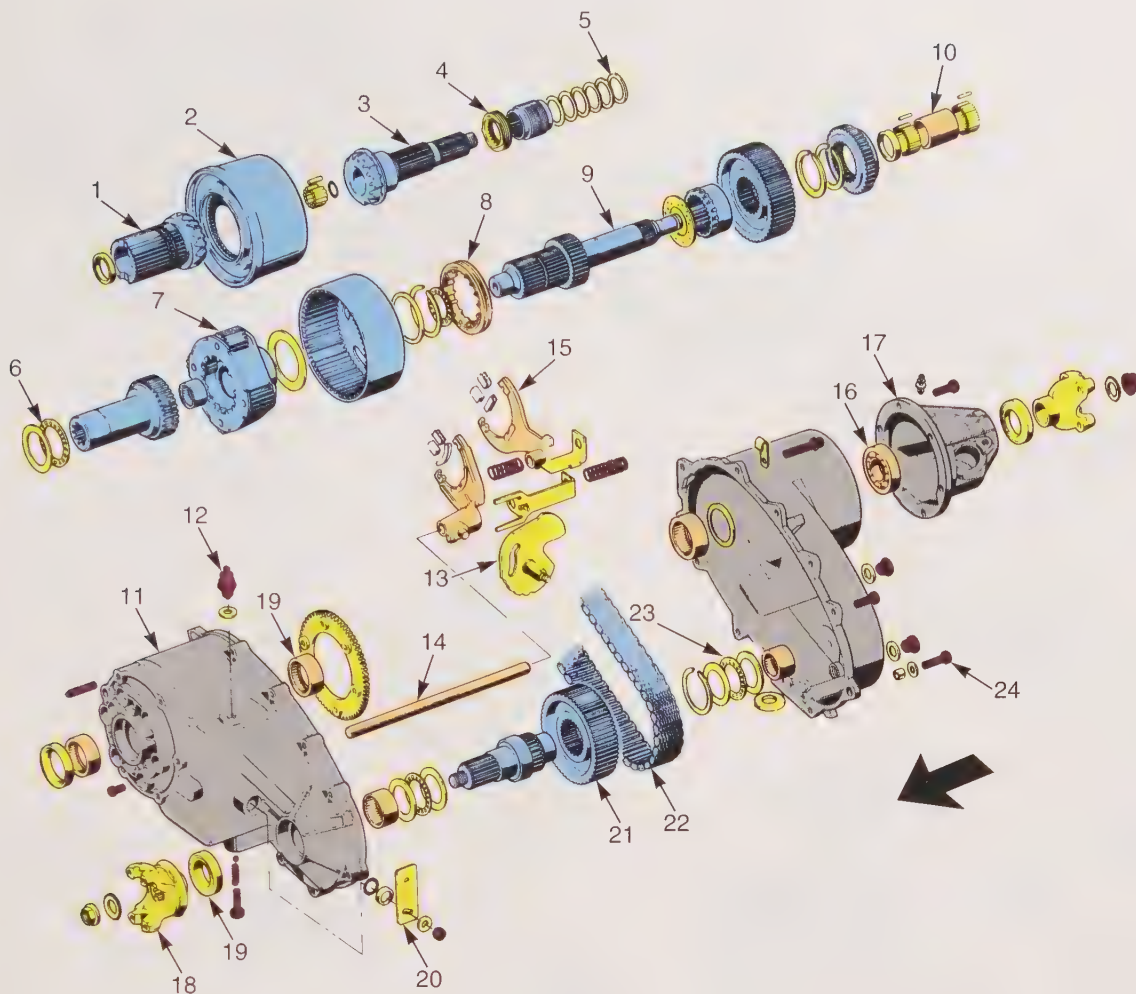
Transfer case failure causing a no-drive condition in all gears is usually caused by stripped gears or splines, a broken drive chain, a broken shaft, or a viscous coupling that has lost its fluid. Generally, a transfer case must be removed from the vehicle to repair these defects.

Abnormal Noises

Abnormal noises in the transfer case include whines and rumbles that occur during operation. Other abnormal noises include grinding, knocking, popping, or snapping sounds. Since the transfer case is mounted directly behind the transmission, it is easy to mistake transmission or drive shaft noise for transfer case noise. Always make sure the noise is really coming from the transfer case and not from some other part of the vehicle.

Transfer case noises usually vary with driving conditions. If the transfer case is the part-time type, road test the vehicle to determine the mode in which the problem occurs. If the transfer case is the full-time type, the vehicle should be placed on a lift to listen for abnormal noises, such as grinding, knocking, or excessive whining. Remember that normal drive train noises will seem louder when you are under the vehicle.

Typical causes of whining or rumbling noises in the transfer case include a low lubricant level, worn or damaged input gear, worn or damaged driven gear, worn



1. Damaged input gear
2. Leaking viscous coupling
3. Damaged splines
4. Damaged speedometer gear
5. Improper spacer thickness
6. Worn or damaged thrust washers
7. Damaged planetary gears
8. Worn or damaged shift collar
9. Damaged shaft
10. Damaged spacer
11. Cracked case, leaking sealing surface
12. Defective electrical component

13. Bent or damaged internal shift linkage
14. Bent shift rod
15. Bent or damaged shift fork
16. Worn or damaged bearing
17. Damaged or warped extension housing
18. Cracked or broken yoke
19. Leaking seal
20. Bent or damaged external shift linkage
21. Worn sprocket
22. Worn or stretched chain
23. Bent or expanded snap ring
24. Loose or missing fasteners

Figure 19-2. This figure illustrates the typical problems that can occur in a chain drive transfer case. Problems can also occur in the oil pump, motor-encoder, and clutch plates, when used. (Chrysler)

bearings, worn planetary gears (where used), and damaged input or output shaft bearings. If the speedometer gears are installed on the transfer case, check them for damage. A worn drive chain can cause popping or snapping noises as the vehicle is accelerated. Sometimes, the transfer case will be noisy because the front and rear axle ratios do not match due to modifications. This can cause friction in the transfer case planetary gears or coupling. To repair damaged or worn transfer case parts, the unit must be removed and overhauled.

Gear Disengagement

When the transfer case jumps out of gear, its shift mechanism moves into Neutral at undesirable times. The first step in troubleshooting this type of problem is to determine the gear in which the problem occurs. If the problem occurs in all gears, it may be caused by loose bolts on the transmission or transfer case, loose or misaligned linkage, interference between the linkage and other parts of the vehicle, or a lack of lubricant on the linkage.

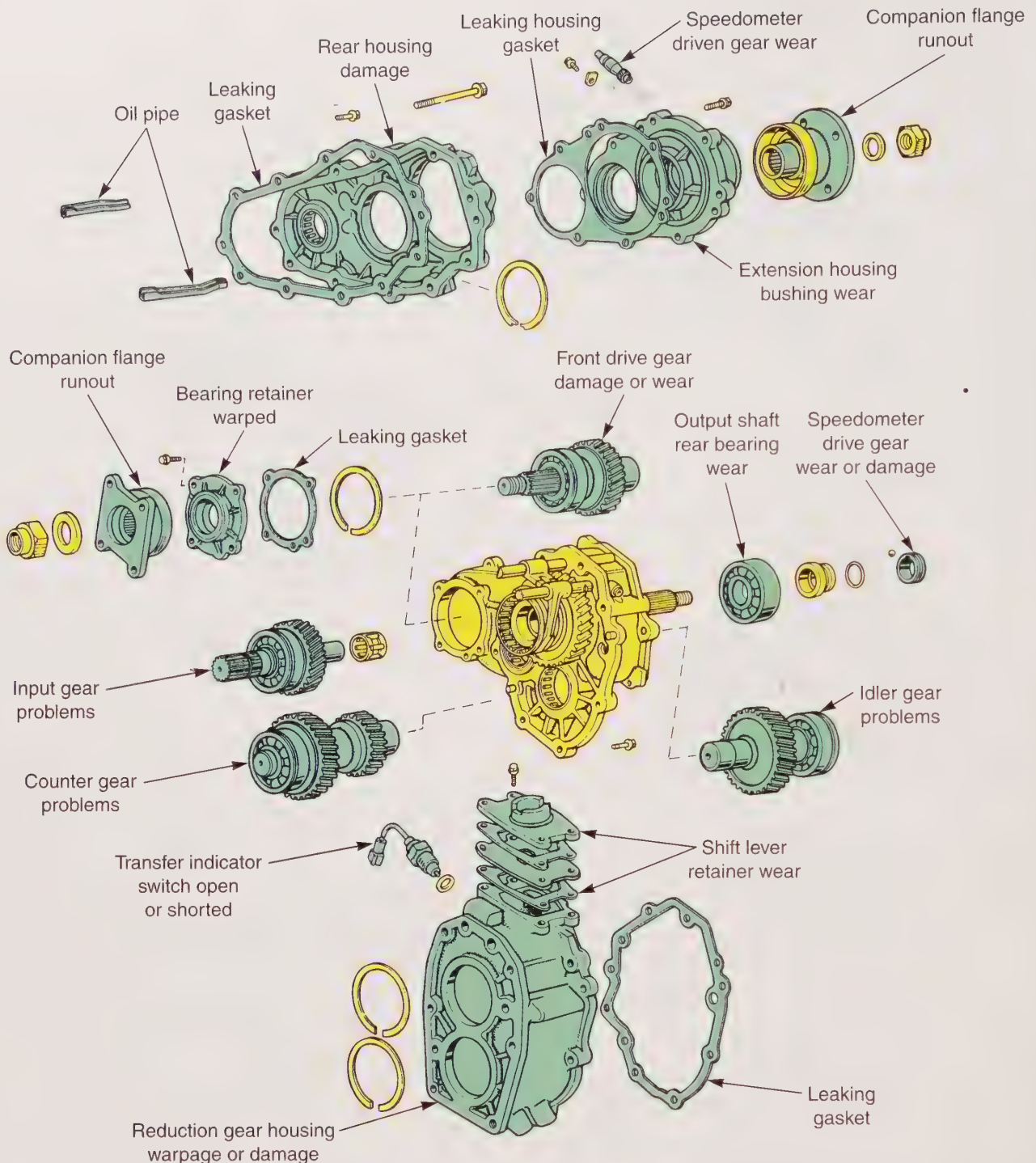


Figure 19-3. Exploded view of a gear-type transfer case showing the typical problems that can occur. These problems are similar to those encountered in a manual transmission. (Toyota)

If the problem occurs in only one gear, the teeth on that particular gear may be chipped or worn. Further, a blocking ring of a sliding clutch assembly may be worn or the splines on or for the sliding clutch of the affected gear may be worn.

Hard Shifting

Hard shifting occurs when the operator must use excessive force to change transfer case gears. Sometimes

binding at the linkage pivot points can cause a hard shifting problem. Before making other linkage inspections, check pivot points and lubricate if necessary. Hard shifting can sometimes be corrected by shift linkage adjustment. **Figure 19-5** shows common shift linkage adjustment points. Any bent or worn shift linkage may cause hard shifting and should be replaced as necessary. If the external linkage is working correctly, bent or worn shift forks in the transfer case may be causing the problem. The transfer case must be disassembled to check.

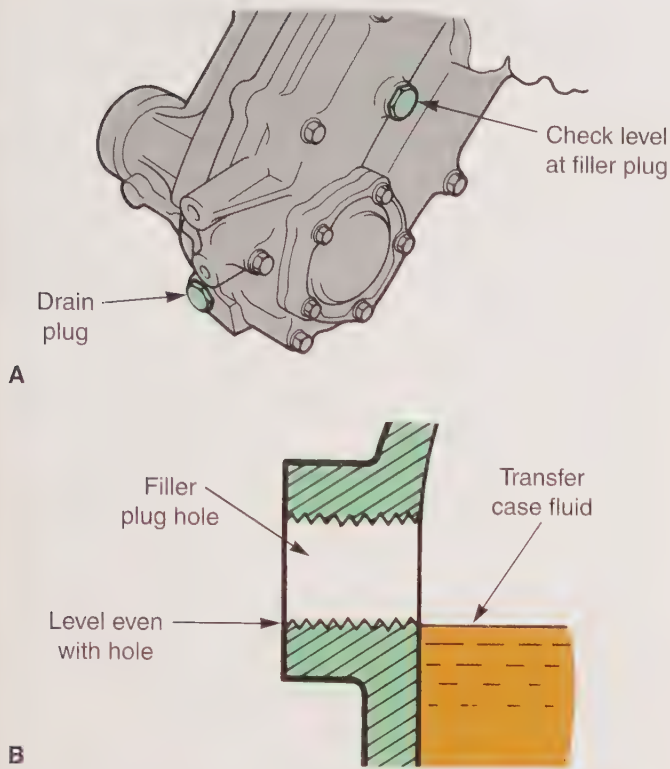
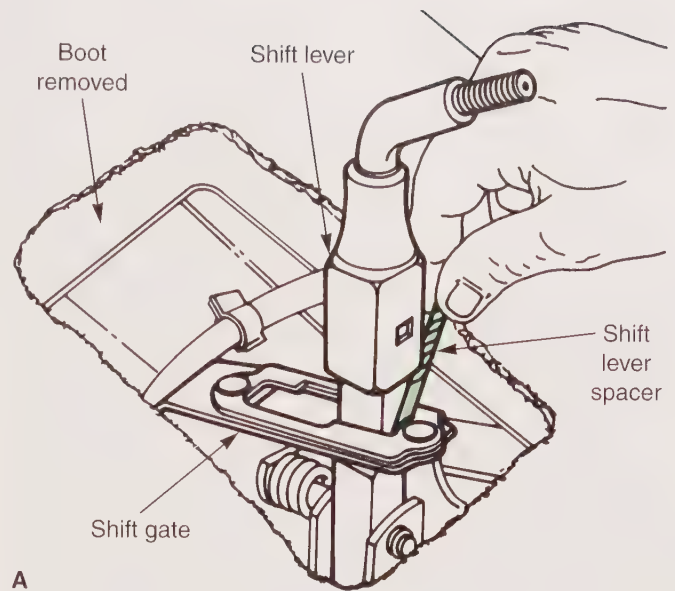


Figure 19-4. Oil level should be checked when troubleshooting transfer case problems. Some transfer cases are lubricated by the transmission fluid. In these systems, the transmission fluid level should be checked. A—Many transfer cases have a drain plug and a filler plug. Always be sure you remove the filler plug when checking the oil level. B—In most cases, the normal oil level is at the bottom of the filler plug threads. (Toyota)

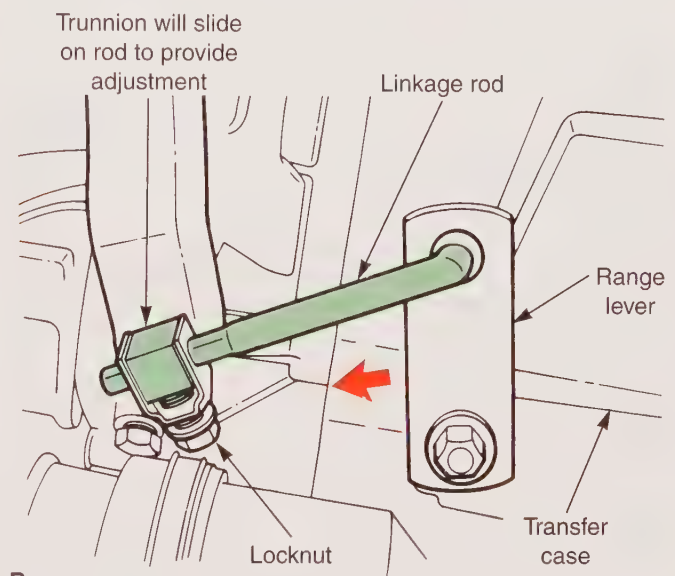
Transfer Case Shudder

Transfer case shudder is a jerking motion that typically occurs during acceleration. Possible shudder causes are low fluid level, loose transfer case fasteners, worn gears or bearings, or defective internal clutches. A shudder may also occur at low speeds on vehicles with a defective viscous coupling or clutch pack.

When diagnosing this problem, make sure the shudder is not caused by the engine, clutch, transmission, limited-slip differential, or universal joints. Check the fluid level, and make sure all fasteners are tight. Pay particular attention to the fasteners holding the transfer case to the rear of the transmission. If fluid level is at the normal mark, and the fasteners are tight, it will probably be necessary to remove and disassemble the transfer case to locate the problem. If the vehicle has a viscous coupling, check for silicone in the transfer case lubricant. Because silicone does not mix with oil, it will appear as globules in the lubricant. This will indicate the silicone has leaked from the viscous coupling and the coupling requires attention. If the viscous coupling has failed, check for different front and rear axle ratios, which may have caused it to fail.



A



B

Figure 19-5. Shift linkage adjustments are critical to proper transfer case operation. Always check the linkage adjustment as part of the troubleshooting process. A—The linkage is sometimes adjusted with the help of a special tool, such as a spacer. B—Sometimes, the linkage adjustment is made with a threaded rod and trunnion that are similar to those used on manual transmission linkage. (Chrysler)

Electronic Transfer Case Problems

The problems of an electronically controlled transfer case often resemble the problems that occur in mechanically operated transfer cases. Other problems are unique to the electronic control system. The following section covers common electronic control system problems.

Many computer control system problems are called pattern failures. A **pattern failure** is a problem that is common to a certain type of vehicle. The experienced

technician will learn to spot pattern failures and quickly determine the commonly defective part.

Input Sensor Problems

Sometimes, the transfer case reacts to problems in the transmission, engine, or vehicle computer. Sensors are the most common cause of electronic transfer case problems. A common problem is improper or erratic range selection caused by a defective speed sensor. Speed sensors can cause problems by sending incorrect engine or output shaft information to the ECM. This usually affects transmission shift speeds as well as transfer case operation. A speed sensor inside the transmission or transfer case can collect metal filings that affect the signal. Some metal particles are always produced as part of normal operation and often become stuck on the sensor magnet.

Temperature and throttle position sensors can indirectly affect transfer case operation. Most defects in these sensors show up first as engine problems.

Output Motor Problems

Output motor problems vary depending on the type motor. Motors can stick in any position. This usually results in the loss of some ranges. Occasionally, a motor will stick at times and work properly at other times. Usual causes of intermittent sticking are a high-resistance winding, a bad electrical connection, or sludge buildup. Erratic operation is a common symptom of an intermittently sticking motor. The transfer case may work well most of the time with only occasional shift problems, or it may shift improperly only when cold or only when hot.

ECM Problems

Since it contains many complex circuits, a failed ECM can cause a variety of problems, depending on what internal part has failed. Sometimes, the ECM will keep the transfer case from shifting. The unit may remain in one range. Another common problem caused by a faulty ECM is erratic shifting. Examples are range changes when speed and road surface are unchanged, or occasionally failing to select the appropriate range. The operation of the ECM is often affected by heat. A cold ECM may work well when the vehicle is first driven and cause problems as it heats up.

A defective ECM can lock up, or stick in one mode. Turning the ignition switch off and then back on may temporarily correct the problem. In many cases, a failed ECM will also cause engine drivability problems. A defective ECM can set false trouble codes. Sometimes it sets codes that do not exist. A failed ECM may illuminate the dashboard warning light, usually called a malfunction indicator lamp (MIL), when there is no problem. It may also fail to illuminate the dashboard warning light when a problem is present.

Wiring and Connector Problems

The voltages used to operate the sensors are usually much lower than battery voltage. Therefore, any wire damage or corrosion at the connectors greatly affects the sensor inputs to the ECM. Note that even slight resistance can cause incorrect sensor inputs, leading to improper or erratic operation. A commonly overlooked wiring problem is a corroded ground connection or disconnected ground wires. Remember that the return path for the current is as important as the input path. Resistance through a ground circuit can affect several control loops at once. Therefore, when a transfer case control system seems to have several unconnected or intermittent problems, look for a poor ground.

Often a wire has been chafed or broken by movement. This commonly occurs where wires must pass through confined spaces or small openings in the body or other sheet metal. Manufacturers often place electrical connectors near or under the vehicle battery. The battery acid and hydrogen gas often cause corrosion inside the connector. A very common wire problem occurs when a wire touches an exhaust system part. The insulation melts, and the wire grounds against the exhaust.

Transfer Case Electrical Checks

Before proceeding with electronic tests, make some basic electrical checks. Begin by ensuring that the system fuses are not melted (blown). There may be more than one fuse controlling the system.



Note: Do not remove any fuses until you have retrieved trouble codes from the ECM. Removing the ECM fuse causes the ECM to lose all memory, including stored trouble codes.

Next, make a careful inspection for obviously burned, chafed, and disconnected wires. In some cases, the wiring harness wrapping may have to be pulled back to expose damaged wires. Be sure to look carefully for burned insulation at all fusible links, and pull on them to determine whether the wire has broken internally. Fusible links are usually located at the battery positive terminal, a nearby power relay, or at the starter solenoid.

Check all vehicle ground wires. On many vehicles, several ground wires are attached to one of the bolts on the engine thermostat housing. These wires can become corroded due to slight coolant leaks. Often, they are removed during cooling system service and are not reattached.

Using Scan Tools to Check the Transfer Case

If the above checks do not reveal a problem, the next step is to obtain a scan tool. The scan tool, as discussed in Chapter 3, is a hand-held electronic device used to retrieve trouble codes and perform other diagnostic functions, **Figure 19-6**. Many scan tools can be used to reprogram the vehicle computer. The scan tool can be thought of as a portable computer that can communicate with the vehicle computer. While they are expensive, scan tools are becoming common because they save diagnostic time and reduce the chance of misdiagnosis. The scan tool also allows the technician to obtain information directly from the ECM. This information would not be available by any other means.



Caution: On OBD II equipped vehicles, the proper scan tool *must* be used to retrieve trouble codes. Do *not* attempt to retrieve trouble codes from an OBD II system by grounding one of the data link connector terminals. Grounding any terminal will damage the ECM.

The scan tool must be connected to the system through the data link. Always locate the proper connector. On OBD II vehicles, a 16-pin connector is used to access all vehicle computer systems. On older (non-OBD II) systems, there may be several connectors for the engine, drive train, antilock brakes, air conditioner, and suspension.

The benefit of the modern scan tool is that it increases the amount of information available to the technician. It also makes it easier to misunderstand what the information means. For instance, with hundreds of potential trouble



Figure 19-6. A scan tool is used to perform various computer control system troubleshooting functions. Scan tools can be used to retrieve trouble codes and obtain readings from sensors and output devices. Some scan tools can be used to reprogram the vehicle computer. The scan tool shown here is used to troubleshoot OBD II systems.

codes, it is easy to look up the wrong code. Sometimes, the amount of available scan tool information can cause the technician to misjudge the actual cause of a problem. For this reason, you must carefully interpret all codes and other scan tool information before proceeding with diagnosis and repair.

Trouble Codes

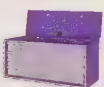
The diagnostic trouble codes for most computer-controlled vehicles are generated as two- or five-character codes that correspond to specific problem areas. Older scan tools display trouble codes as numbers and letters. The technician must match these codes to specific problems by looking up the code in the service literature. Newer scan tools process the code letters and numbers, and produce readouts that describe the actual problem. Some scan tool software can also suggest possible solutions and tell the technician if the problem is common on the vehicle being tested.



Note: Remember that a trouble code does not necessarily mean that a computer system part or circuit is defective.

OBD I systems normally display two-digit trouble codes. These codes are correlated to a specific sensor or circuit. In a few cases, the code will specify a certain problem, such as low- or high-voltage readings. In most cases, however, the code will simply indicate that there is a problem in the system.

OBD II systems display five-character alphanumeric codes consisting of one letter and four numbers. The letter identifies the general function of the vehicle system causing the problem. The first number indicates whether the code is a standardized code (code assigned by SAE) or a manufacturer-specific code. The second number indicates the specific system causing the problem. The last two numbers, which are called the **fault designers**, identify the specific component (sensor, output device, or ECM) that might be at fault, as well as the type of fault detected.



Note: OBD II trouble codes do not correspond with OBD I codes. Never try to correlate the older trouble codes with OBD II fault designers.

In OBD I systems, the two-digit format limits the number of trouble codes to 100. In the five-character OBD II format, there are over 8000 potential codes. While all this capacity is not presently being used, a modern vehicle ECM may be programmed with several hundred trouble codes. Of course, not all of these codes apply to the transfer case.

Newer OBD II scan tools access the ECM and sensors to provide the technician with readings of engine speed, vehicle speed, and current transmission and transfer case gear ranges. These scan tools also display the desired gear for the particular engine and vehicle speed. The technician can instantly determine whether the transfer case is in the proper gear. Other inputs give exact engine timing in degrees, actual engine temperature, transmission and intake air temperature, and air-fuel ratio. The scan tool can also provide voltage or duty cycle readings that indicate operating conditions of emission control devices. OBD II ECMs and scan tools can also tell the technician whether or not there is an engine miss, and on which cylinder.

Some scan tools can interface with the ECM to provide snapshots, or freeze frames, of engine and drive train operation. The snapshot is a scan tool feature that records vehicle operating conditions just before and just after a malfunction occurs. This allows the technician to determine exactly what happened to cause the problem. To record the snapshot information, the technician only has to drive the vehicle with the scan tool attached to the data link connector until the malfunction occurs. The technician can then access the readings through the scan tool. Some ECMs save snapshot-type information when the malfunction occurs during normal operation. The technician can obtain the saved information by attaching the scan tool to the diagnostic connector.

Other Scan Tool Data

The scan tool can also be used to view data stream information from the computer as the vehicle is operated. Typical data stream information includes engine rpm and temperature, sensor inputs, speeds at which automatic transmission shifts and converter clutch application occur, vehicle speed, and outside air temperature.

Scan tools can also be used to test output devices by bypassing the ECM and commanding them to operate. One of the most useful ways that a scan tool can be used is during a road test. Attach the scan tool to the vehicle's data link connector and place the scan tool on the dashboard or seat to observe readings as you drive the vehicle. Transfer case ranges, transmission shift speeds, engine rpm, and other data can be observed under actual driving conditions.

Retrieving Trouble Codes without a Scan Tool

On a few older self-diagnostic systems, usually called OBD I systems, the trouble codes may be accessed by grounding a terminal on the data link connector. Once the terminal is grounded, the codes will be displayed by a series of flashes of the dashboard "check engine" or "service soon" light. Usually the system will flash a trouble code three times, followed by a short pause before it flashes the next trouble code. Most OBD I

systems have a two-digit trouble code system. The two-digit system limits the number of trouble codes to 100. Remember that most older transfer cases are not connected to the ECM and there may not be any transfer case-related trouble codes.

On one type of older system, grounding the data link connector will cause the trouble codes to be displayed by flashing the transfer case control buttons. The number of flashes indicates the trouble code(s). As with other OBD I systems, each series of number flashes is separated by a short pause.

Checking Component Operation

Once you have isolated the problem by the above test procedures, you can proceed to check individual components. Testing the operation of individual components is covered in the following sections.

Test Equipment

To test electronic components, you will need some or all of the following testers. This test equipment was discussed in Chapter 3 and will be briefly reviewed here. Scan tools were also discussed in the previous section.

Using Nonpowered and Powered Test Lights

Both nonpowered and powered test lights are useful tools to test for the presence of voltage and circuit continuity. There are specific procedures for using each type of test light. They are outlined in the following paragraphs.

To use a nonpowered test light to check for voltage, connect the alligator clip to a good ground. Touch the probe to the terminal or point to be tested. The test light will illuminate if voltage is present. If voltage is low, the light will glow dimly. To test for ground, connect the alligator clip to battery voltage and touch the probe to the circuit's ground terminal. If the ground is present, the light will glow brightly. If the light does not come on, the ground circuit is open. If the light glows dimly, the ground circuit has excessive resistance.

To use a powered test light, begin by disconnecting all electronic components in the circuit. Connect the test light's alligator clip to the terminal at one end of the circuit. Use the probe to touch the other terminal in the same circuit. If the circuit has continuity, the test light will brightly illuminate. If there is excessive resistance in the circuit, the light will glow dimly. If there is an open in the circuit, the light will not come on.



Caution: Do not use a test light to check any electronic circuit unless the manufacturer specifically recommends its use. The current flow through a test light can damage most electronic circuits.

Using Voltmeters

Voltmeters can be connected to read the voltage that is available at an electrical connection. Voltmeters are always connected parallel to the circuit to be tested. (See Appendix A.) The voltmeter in **Figure 19-7** is being used to measure the voltage at a wire connection. To check the voltage drop of a connection, simply attach the leads on either side of the connection. If the connection has excessive resistance, current will try to flow through the meter rather than creating a voltage reading. The connection must be cleaned or replaced if the voltage is higher than the maximum specified.



Caution: When measuring for an unknown voltage, always set the voltmeter to the highest voltage setting to avoid damaging the meter.

Using Ammeters

Ammeters can measure amperage flow of up to ten amps and are connected in series with the circuit. (See Appendix A.) More amperage will damage the ammeter, so most modern ammeters are equipped with an inductive pickup, **Figure 19-8**. This pickup is clamped over the current carrying wire. The pickup reads the magnetic field created by the current flowing through the wire and converts it into an amperage reading.



Caution: Always set the ammeter to the highest amperage setting when troubleshooting a circuit. A faulty component can cause higher than normal current to flow through the ammeter, causing damage.

Using Ohmmeters

Ohmmeters are connected across the part or circuit to be tested, with circuit's power off, and are used to check for continuity or the presence of resistance. A wire's

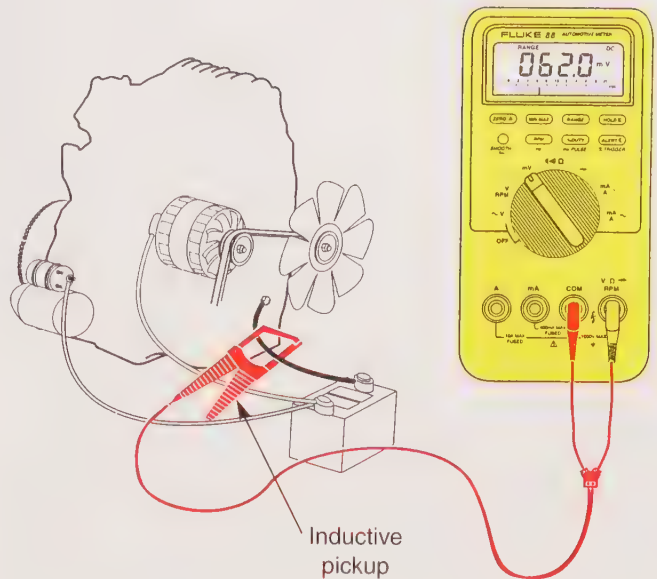


Figure 19-8. The inductive pickup allows the multimeter to take high amperage readings without damage. An inductive pickup also eliminates the need to remove wiring harness connections. (Fluke)

resistance should be at or near zero. **Figure 19-9** shows a method of checking solenoid resistance. The resistance of an electronic part should be as specified in the service literature.



Caution: When checking for continuity or resistance, be sure to remove power from the circuit before connecting the ohmmeter. An energized circuit could damage the ohmmeter.

Modern voltmeters, ammeters, and ohmmeters are combined into a single unit called a multimeter. A multimeter used on any electronic system must have a high resistance to current flow to prevent damage to the meter or to the part being tested. Many solid-state components, such as ignition modules and ECMs, can be severely damaged by careless use of test lights and multimeters.

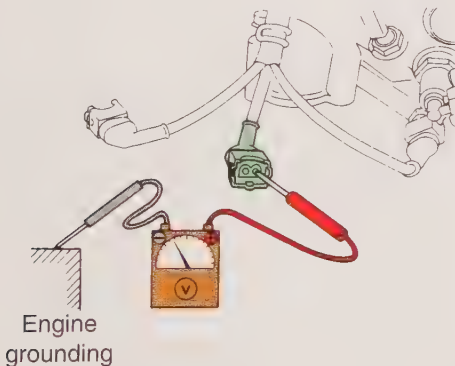


Figure 19-7. The attachments in this figure allow the multimeter to take voltage readings. Voltmeters can also be used to check for high resistance across an electrical connection. (Subaru)

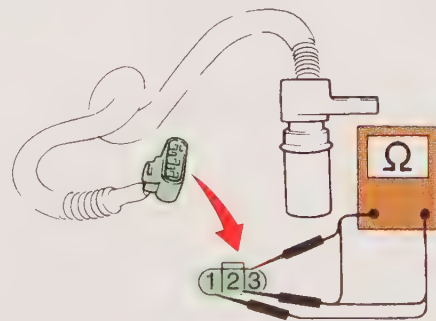


Figure 19-9. Ohmmeters are useful for checking the resistance of suspect electrical devices, such as this speed sensor. They can also check for continuity across switches and the condition of electrical connectors. (Nissan)

Specialized testers are often needed to check the operation of specific electronic devices or systems.

Temperature-sensing tools can determine the exact temperature of the engine or transmission. The actual temperature can be compared with the sensor readings recorded by the scan tool to determine whether or not the sensor is sending the correct temperature to the ECM.

System Operation Testing

Once a suspect system has been isolated, the technician should determine whether that system and its components are working correctly. The easiest way to diagnose an electronic control system is by using the proper scan tool. If the transmission is operable, drive the vehicle and observe the applicable scan tool readings. At the same time, observe transfer case operation.

During the test-drive, note the transfer case range selection pattern. Also note any slipping, harsh engagements, or noises. Try to match the malfunction with the scan tool readings. This should give you some idea of what the problem consists of. It will also give an indication of which gear has a problem. With this information, you should be able to proceed to check the affected components and systems.

Component Testing

There are three major ways to test individual electronic transfer case components: visual checks, electrical tests, and testing by substitution. General information on making these tests is given in the following sections. Before performing the individual component testing, be sure to read the general information presented in the following section.

Making visual checks

You have already performed some visual checks as part of your preliminary diagnosis. If the problem is in a specific system, check the system for disconnected or damaged wiring, obvious component defects, or problems in related areas. For instance, if your preliminary investigation indicates a problem in the front axle speed sensor, do not assume the sensor is bad. First, check the electrical connections to the sensor and look for metal buildup on the sensor nose.

Making electrical tests

Some motors can be tested by making a continuity check or by applying current and observing motor operation. Motor operational checks can be made with jumper wires. Some motors and other components can be checked through the wiring harness without removing the part from the transfer case. However, you must refer to the proper service manual to determine which connector pin energizes which component.



Caution: Some procedures call for energizing a motor or other device with battery voltage. Always consult the proper factory service manual to be sure the device is designed to operate on full battery voltage. Some electrical devices will be destroyed if full battery voltage is applied. When using jumper wires to operate a solenoid or other device, be sure the wiring to the ECM is disconnected. Full battery voltage to some ECM connectors can destroy the ECM.

Although most solid-state components require specialized test equipment, some basic checks can be made to some solid-state components. A few solid-state components can be checked for proper operation. Common checks include using an ohmmeter to check a terminal for proper grounding. This check must be made very carefully to avoid damage to the unit. The circuits in solid-state components are extremely small and are usually designed to respond to voltage changes only. Any amperage flow would damage them. Amperage (current) flow through most test equipment is enough to overload and burn up circuits in solid-state components.

When checking any electrical component for proper voltage or resistance, consult the manufacturer's service information to determine what the readings should be.

Testing by substitution

In many cases, the only way to determine whether a component is defective is to substitute a known good unit for the questionable component. When testing by substitution, however, the technician must keep the following things in mind:

- ❑ Obtaining a known good part may be expensive and time consuming. In many cases, especially when substituting an electrical or electronic part, the part may not be returnable.
- ❑ If the actual problem is a short or a high amperage draw somewhere else in the system, the heavy current flow may ruin the substituted part.
- ❑ If the part requires a great deal of labor (time) to install, this labor will be wasted if the replaced part is not the problem.

Eliminate all other sources of problems before substituting a part. Always consult the manufacturer's manual to determine whether a suspect part can be tested before replacing it. Technicians can partially offset the problem of obtaining substitute parts by acquiring a stock of commonly needed known good parts.

Replacing Electronic Transfer Case Components

This section covers replacement of electronic transfer case components. Nonelectronic components are similar to those used on other transfer cases and are covered in later sections of this chapter.

Speed Sensors

Most speed sensors are located on the transmission or transaxle case. To replace a speed sensor, remove the electrical connector. Then, remove the bolt holding the sensor to the case and remove the sensor. Compare the old and new sensors to ensure the new sensor is correct. Be sure the new sensor is not longer than the old sensor, or it will contact the moving input shaft when installed. Install the new sensor in the case and install the hold-down bolt and electrical connector.

ECMs

Before replacing an ECM, make sure the ignition switch is turned to the *off* position. If the manufacturer recommends it, disconnect the negative battery cable. Locate the ECM, disconnect the wiring connector(s), and remove the attaching fasteners. Most ECMs are attached with bolts or screws, but a few are simply clipped in place or held in place with plastic rivets behind a trim panel. If the ECM has one or more ground straps, remove them last.

To replace the ECM, set the unit in place and reinstall the fasteners, being sure to reattach any ground straps. Then, reconnect the electrical connectors. On some vehicles, it may be necessary to connect the wiring before installing the ECM in position.

Many ECMs can be restored to proper performance by providing them with updated information. On some older vehicles, the PROM chip (sometimes called a mem-cal chip) can be replaced. On many late-model vehicles, the ECM can be reprogrammed from an outside source. These processes will be outlined in the following sections.

Replacing a PROM

To replace a PROM, make sure the ignition key is in the *off* position. Remove the ECM fuse and remove the access cover over the PROM. Special tools are available to help remove and install the PROM safely. Remove the old PROM from the ECM. Then install the new PROM, carefully pushing it into position. Finally, replace the access cover and reinstall the ECM fuse.

Replacing a knock sensor module

In some vehicles, the ECM contains a knock sensor (KS) module. This module can be replaced if it is defective. Additionally, it can be removed from a defective ECM and reinstalled in a new unit, ensuring that the proper timing retard is maintained for engine knock protection.

To replace the knock sensor module, make sure the ignition key is in the *off* position. Remove the ECM fuse and then remove the access cover over the KS module. Pinch the module locking tabs to release them and pull the module from the ECM.

Install the new module carefully, making sure the mounting pins are not bent. When pushing the KS module into position, make sure the module's locking tabs snap into place. Finally, replace the access cover and reinstall the ECM fuse.

Flash programming a computer

As mentioned, the ECMs in late-model vehicles can be updated by erasing old information from the computer's memory and reprogramming the unit with new information. The new information often cures engine driveability and transmission shifting problems. The computer memory section that can be updated is generally called the **EEPROM** (electronically erasable programmable read-only memory) or the **FEPROM** (flash erasable programmable read-only memory). Providing the existing memory with updated information is usually referred to as **flash programming**.

Actual reprogramming details vary between manufacturers, but the basic procedures are the same for all vehicles. One of three methods can be used to reprogram the ECM:

- ☐ Direct programming.
- ☐ Indirect programming.
- ☐ Remote programming.

Direct programming is the fastest and simplest method of reprogramming an ECM. The new information is downloaded by attaching a shop recalibration device (usually a computerized analyzer) or a programming computer directly to the vehicle's DLC. See **Figure 19-10A**. The erasure and reprogramming is done by accessing the proper menu and following the instructions as prompted by the recalibration device. Then, the information (often stored in

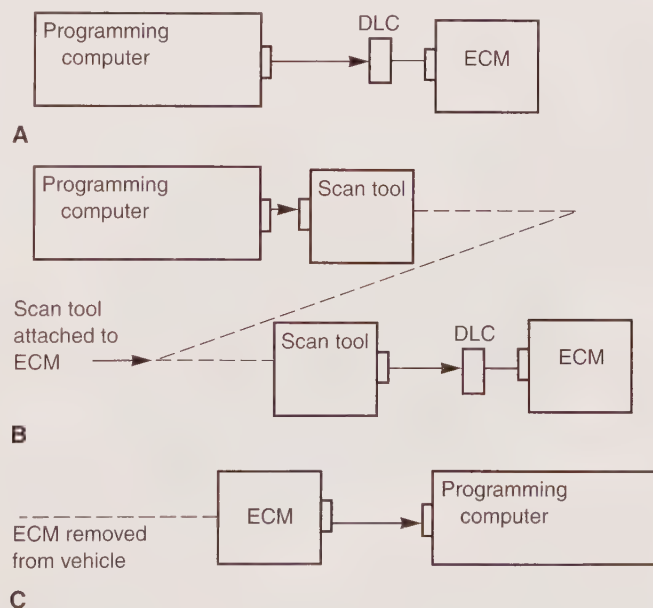


Figure 19-10. Flash programming methods. A—Direct programming. B—Indirect programming. C—Remote programming.

the device's memory, contained on a CD-ROM, or accessed through a connection to the manufacturer's database) is entered into the ECM through the DLC. The shop recalibration device is not a scan tool, and a scan tool is not needed for this programming procedure.

To perform **indirect programming**, the proper scan tool is used to transfer information from a separate programming device to the ECM. See **Figure 19-10B**. The scan tool can also be used to reset some computer-controlled vehicle systems after programming is complete. The **programming device** may resemble a personal computer used in the home, or it may be a computerized analyzer that is similar to the one used for direct programming.

In indirect programming, the scan tool is connected to the programming computer and programming information is downloaded from the computer to the scan tool. Most scan tools use a high-capacity memory cartridge to store the programming information. Some newer scan tools have enough fixed memory to hold the programming information and do not use a separate memory cartridge. Once the programming information has been downloaded, the scan tool can be disconnected from the programming computer, taken to the vehicle, and connected to the DLC. Programming information is then downloaded from the scan tool to the ECM through the data link connector.

Remote programming is done with the ECM removed from the vehicle. See **Figure 19-10C**. This procedure is used when changes must be made through a direct connection to a manufacturer's database. Remote programming can also be done in cases where normal direct or indirect programming is not practical or possible. Special connectors and tools are required for remote programming. In most cases, this procedure is done only at new vehicle dealerships.

To perform remote programming, remove the ECM from the vehicle as described earlier in this chapter. Once the ECM has been removed, take it to the programming device. The programming device is generally a computer located in the shop. This device may contain the new ECM information, or it may be used with a modem to connect to a remote database. Attach the programming device's electrical connectors to the ECM. Access the device's programming menu and follow instructions given in the menu to program the ECM. Programming normally takes only a few minutes. When programming is complete (as indicated on the menu), remove the programming device's electrical connectors from the ECM and reinstall the ECM in the vehicle.

Transfer Case Shift Motors

To replace a transfer case shift control motor, it may be necessary to remove the **skid plate** (protective undercarriage panel) or splash shield under the transfer case. Most shields and plates are bolted into place. With the shield or plate removed, disconnect the electrical connector. Then remove the bolts or screws holding the motor to the transfer case. Gently pull the motor from the transfer case.

Remove any old gasket material from the transfer case housing, and then install a new gasket on the housing. Next, position the motor in place, making sure the motor and internal shift mechanisms are engaged. Then, install and tighten the motor fasteners. Always reuse the original fasteners or obtain the correct replacements. Using the incorrect fasteners will cause corrosion on magnesium transfer case housings. Replace the electrical connector and reinstall the skid plate or splash shield.

Rechecking System Operation

After replacing parts or reprogramming the ECM, recheck system operation to ensure that the repairs have been successful. Drive the vehicle long enough for the transmission or transaxle to shift through all the gears. Check part throttle downshifts and detent (passing gear) operation, if possible. While making the test-drive, note whether the MIL light comes on. When the road test is complete, use the scan tool to recheck the system for trouble codes.

ECM Relearn Procedures

The electronic control system may require a **relearn procedure**, which is a period of vehicle operation that allows the computer system to adapt to new components and updated reprogramming. The relearn procedure can often be accomplished by driving the vehicle at various speeds for about ten minutes. Some vehicles require a specific relearn procedure, which may include idling in drive for a specified amount of time or until the engine reaches its normal operating temperature. Always check the manufacturer's service information for specific relearn procedures. Ignore any unusual engine and transmission conditions until the relearn procedure is complete.

Transfer Case Overhaul

Many of the problems encountered in four-wheel drive systems result from improper transfer case operation. Worn or damaged transfer cases must often be removed from the vehicle for service. The following sections outline the procedures for removing, servicing, and reinstalling a typical transfer case.

Transfer Case Removal

Transfer case removal is similar to manual transmission removal. Nevertheless, recommended removal procedures may vary among manufacturers. Therefore, this section covers only the basics of transfer case removal. Always obtain the proper factory service information for the particular model you are servicing. The information will contain important details. For example, it will tell you if the transmission and transfer case should be removed as a unit.

Figure 19-11 shows some of the parts that may need to be removed in order to remove the transfer case. The general procedure for removing a transfer case is as follows:

1. Disconnect the negative battery cable. This will prevent accidental operation of the starter when you are working on the vehicle.
2. Raise the vehicle with an approved hoist or hydraulic jack. If using a hydraulic jack, be sure to install good quality jack stands before getting under the vehicle. If the vehicle has an off-road skid plate or splash shield, remove it. Drain the oil from the transfer case. Sometimes the transmission and transfer case share the same oil. In these systems, it may be necessary to drain the oil at the transmission.
3. Place a transmission jack or stand under the transmission. This helps support the transmission and transfer case during removal.
4. Remove any ground straps and electrical connectors from the transfer case and remove the speedometer cable assembly. Disconnect the transfer case shift linkage and, if necessary, the transmission shift linkage. Vehicles with full-time four-wheel drive or electronic transfer cases usually do not have linkage on the transfer case.
5. Mark the drive shafts or yokes so they can be correctly reattached to the transfer case. Then, remove the drive shafts from the transfer case. It may not be necessary to remove the drive shaft assemblies from the vehicle. If possible, leave them attached at the differentials and secure them to the underside of the chassis with wire.
6. If necessary, raise the transmission slightly and remove the rear engine mount and cross member.
7. Remove any brackets or fasteners holding the transfer case to the vehicle frame.
8. Place a transmission jack (or floor jack) under the transfer case. Then, remove the bolts or nuts holding the transfer case to the transmission.



Warning: If the transfer case is not properly supported, it will drop when the bolts holding it to the transmission are removed, causing injury or damage.

9. Slide the transfer case away from the transmission and lower the case. Note that the transmission output shaft extends into the transfer case. During removal, the transfer case must be moved away from the transmission until it clears the output shaft. As you lower the transfer case, make sure it does not catch on adjacent parts. Also, make sure all straps, wires, and other attachments have been disconnected.

Transfer Case Disassembly

After removing the transfer case, drain any remaining oil. Clean the outside of the housing and mount the unit securely on a clean workbench. Make sure the transfer case will not fall off the bench during the disassembly procedure.

If not removed previously, remove the drive shaft yokes. Most drive shaft yokes are secured to the output shafts with large nuts. The nuts can be removed with the proper wrench. The yoke should be held securely with a special tool or a large pipe wrench as the nut is loosened. Mark the front and back yokes to ease reassembly.

Remove the speedometer gear and housing from the transfer case. Also, remove electrical switches and other external transfer case parts as necessary.

If the transfer case housing is the common two-piece type, **Figure 19-12**, remove the bolts holding the front and rear halves together. The halves can then be split apart. If the gasket sticks, pry the halves apart with pry bars, **Figure 19-13**. If the housing is a one-piece type, the front and rear retainers that hold the input shaft bearings should be removed to gain access to the internal parts. See **Figure 19-14**.

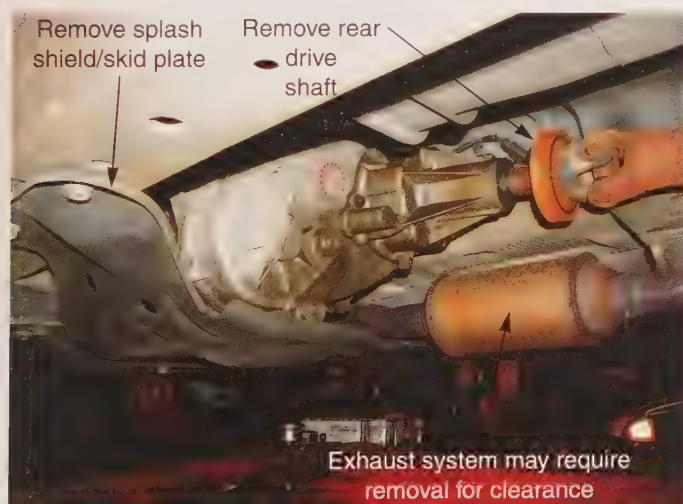


Figure 19-11. This photograph shows some of the parts that must be removed before the transfer case can be removed. In addition to the parts shown, it will be necessary to remove the electrical connectors and/or shift linkage, speedometer cable, and vent tube. Many technicians prefer to drain the lubricant to reduce spillage.

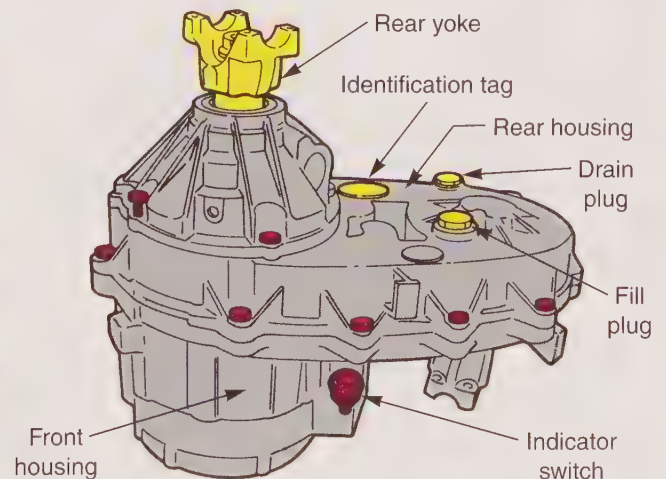


Figure 19-12. This transfer case has a two-piece or split-type housing. The identification tag should be used to order parts and to determine which service specifications to use. (General Motors)

After accessing the internal parts, remove any snap rings that hold the transfer case gears to their shaft or secure the shafts to the housing. Then, remove the internal parts as necessary. All shafts, sliding gears, and planetary gears, if used, should be removed at this time. An exploded view of a typical transfer case is shown in **Figure 19-15**. Refer to the appropriate service information for exact disassembly procedures.

Figure 19-16 shows a technician removing a mainshaft, complete with gears, shift fork, and rail. Removal procedures for other parts are similar. Some transfer cases do not have an input shaft. Instead, the transmission output shaft is splined to the inside of the transfer case input gear. Remove the differential unit, viscous coupling, or clutch drum as applicable.

If the transfer case is equipped with a drive chain, lift the front output shaft, sprocket, and chain out of the case. In many transfer cases, the chain and sprockets are removed as an assembly. In some designs, however, it is necessary to slide the chain off the mainshaft drive sprocket during the removal process. After removing the chain and sprockets, carefully remove any thrust washers that were located under the sprockets.

While disassembling the transfer case, note the relationship of all parts so that they can be reinstalled properly. If necessary, mark the parts with a punch or a scribe to ensure proper reassembly.

Transfer Case Parts Inspection

Before inspecting the transfer case parts, scrape all gasket material from the transfer case housing, being careful not to damage the sealing surfaces. Check the bottom

of the housing for needle bearings or other small parts. Clean the inside of the housing and all internal parts. Make sure all sludge and metal particles are removed.

After cleaning, thoroughly inspect the transfer case housing, bearing retainers, and extension housings for cracks or other damage. Additionally, check all bushings and seals for wear.

All internal transfer case parts should be inspected for wear and damage. Examine all the shaft bearings, needle bearings, shift forks, sliding clutch sleeves, and washers. Replace worn components as necessary.

Figure 19-17 illustrates various checks that should be made to a transfer case planetary gear assembly. Examine the gears for worn, cracked, or chipped teeth. Damaged gears should be replaced. Check for wear between gear bushings and the shafts. Look for wear or damage to the

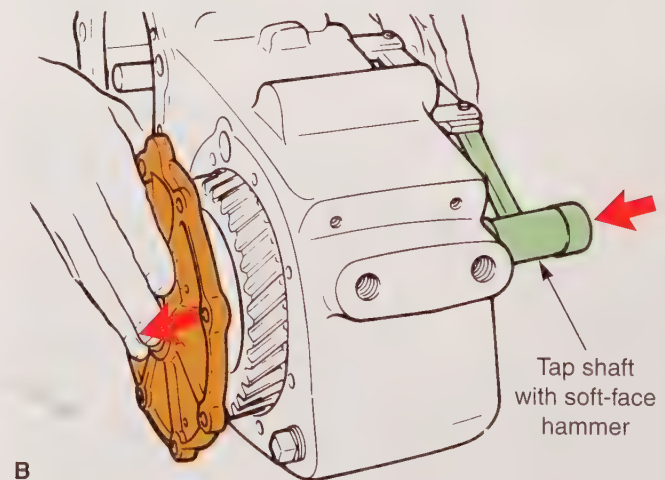
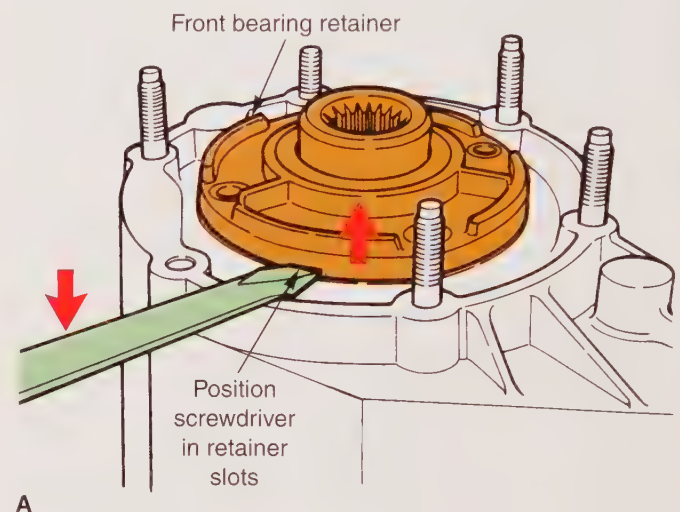


Figure 19-14. Begin disassembly of a one-piece transfer case by removing the bearing retainers. If the drive yokes were not removed during transfer case removal, they should be removed at this time. A—Most bearing retainers can be unbolted from the case and then lightly pried up. B—Basic procedure for removing the bearing retainer and shaft on a one-piece transfer case. Always use a soft-face hammer to avoid damaging the shaft or gears. (Chrysler, General Motors)

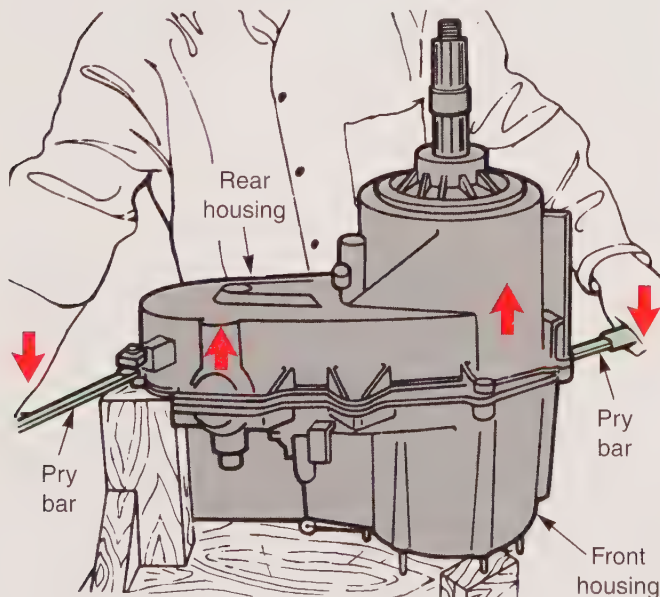


Figure 19-13. If the two halves of the transfer housing stick together, they can be pried apart with two pry bars. Pry at opposite ends of the case to avoid cracking or jamming the case halves. (Chrysler)

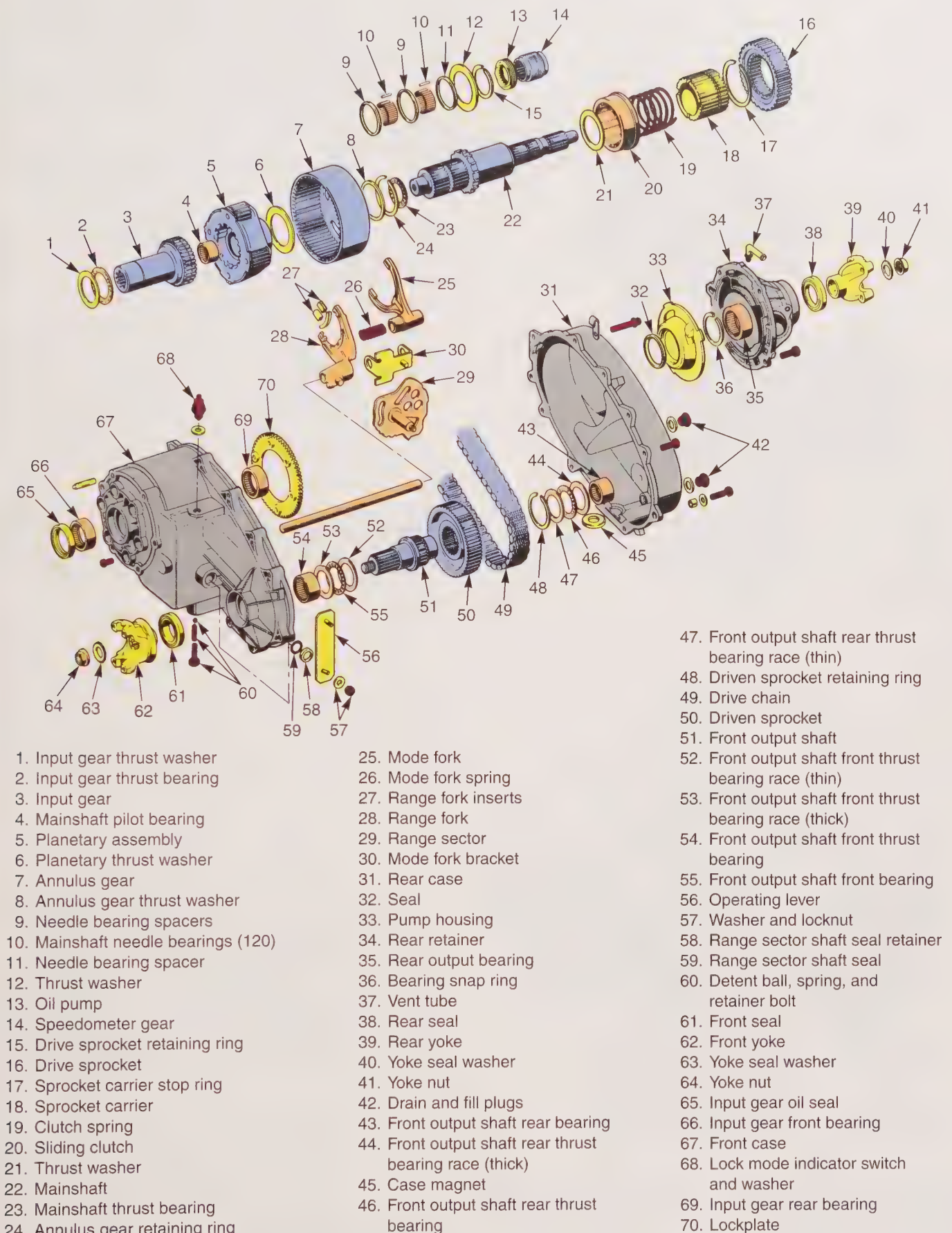


Figure 19-15. Study this exploded view of a typical transfer case. The transfer cases used on many late-model vehicles have planetary gears and a drive chain to transfer power. (Chrysler)

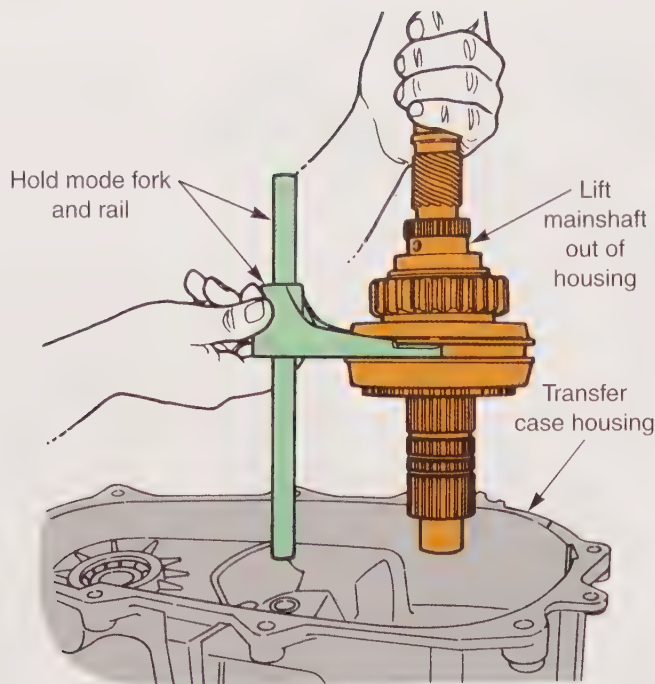


Figure 19-16. Some transfer case shaft and gear assemblies can be removed as shown. In other designs, the gears and the shaft must be removed separately. Always consult the manufacturer's service information for exact disassembly procedures. (Chrysler)

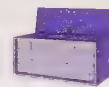
splines on the shafts and to the planetary housings. Splines can strip off so cleanly that splined surfaces appear to be machined smooth. This makes it very important to compare these parts to specifications.

If used, check the transfer case blocking rings of the sliding clutch assembly for wear on the outer teeth. Also, inspect the areas where the inner cone ridges contact the gear cone. (Refer to Chapter 9 for information on checking synchronizer assemblies.) Replace blocking rings showing signs of wear or damage.

It may be necessary to disassemble the mainshaft to inspect the shaft-mounted components. A sectional view similar to the one shown in **Figure 19-18** is helpful when disassembling and reassembling the mainshaft.

Check the sliding clutch sleeves where the shift forks ride. If the shift forks are equipped with separate pads at the riding surfaces, **Figure 19-19**, the pads should be replaced whenever the transfer case is disassembled.

If the transfer case uses a differential assembly or a viscous coupling, it should be checked for wear and damage. Always follow the inspection procedures outlined in the factory service information.



Note: Refer to the index in this textbook for more information on precision measurement, inspection, and other topics that relate to transfer case overhaul.

If the transfer case has a clutch pack, carefully check the condition of the clutch plates. Replace any clutch plates that are worn or burned. Clutch pack clearance is vital to proper operation and must be carefully checked. Adjust clearance by adding or subtracting shims or replacing the existing shims with shims of the proper thickness.

Transfer Case Reassembly

The transfer case should be reassembled in the reverse order of disassembly. Before beginning, replace worn bushings and seals as shown in **Figure 19-20**.

Begin reinstalling the parts in the transfer case. Exploded views, **Figure 19-21** are often helpful in determining where parts are placed. Remember that internal parts must be placed into the case in the proper order. If not, you may have to take the transfer case apart again to install forgotten parts. Reassembly procedures will vary with transfer case design. Nevertheless, the following procedure will serve as a general guide to reassembly.

Assemble the mainshaft gears and hubs onto the mainshaft. Use new parts as needed. Install all internal parts in the transfer case housing. See **Figure 19-22**. Note that the shift forks are usually installed at the same time as the gears they operate. Make sure the shafts are properly seated in the bottom of the housing to avoid binding.

Install the drive chain, making sure the sprockets and shafts are properly aligned with the chain. Refer to

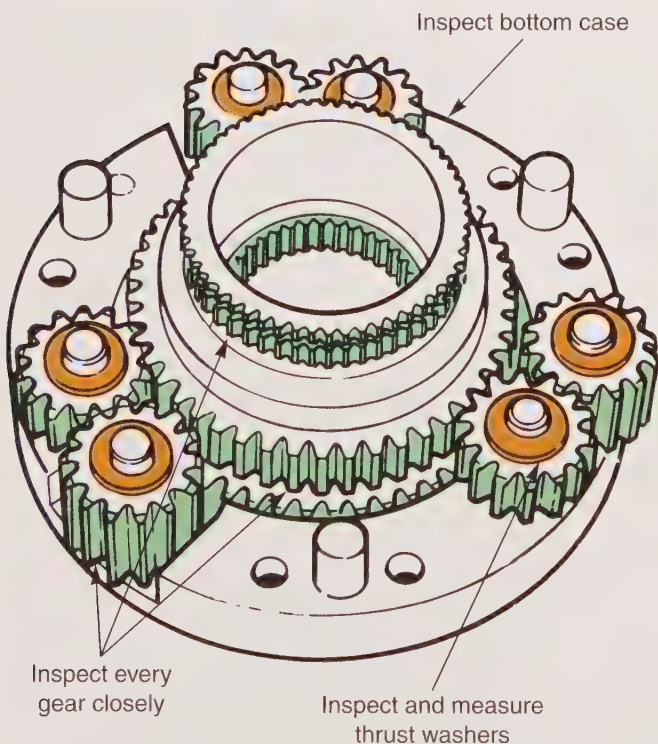
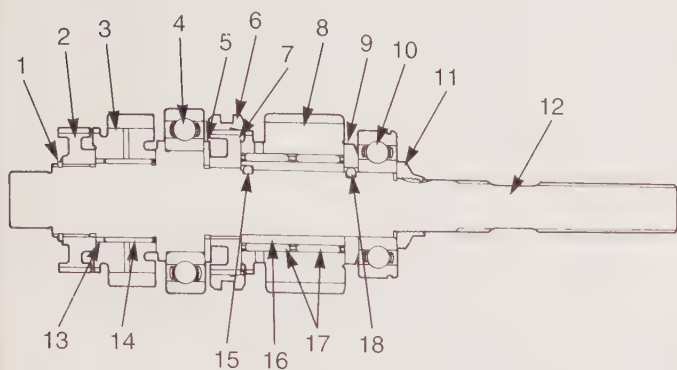


Figure 19-17. Check internal gear parts for wear or chipping at the teeth, wear or damage to internal and external splines, and wear of the thrust bearing surfaces.



- | | |
|------------------------|-----------------------|
| 1. Snap ring | 10. Ball bearing |
| 2. H-L clutch hub | 11. Locknut |
| 3. Low speed gear | 12. Rear output shaft |
| 4. Ball bearing | 13. Thrust washer |
| 5. Stop plate | 14. Needle bearing |
| 6. 2-4WD clutch sleeve | 15. Steel ball |
| 7. 2-4WD clutch hub | 16. Sprocket sleeve |
| 8. Drive sprocket | 17. Needle bearing |
| 9. Sprocket spacer | 18. Steel ball |

Figure 19-18. Assembly details of a transfer case mainshaft. A sectional view such as this one helps the technician disassemble and reassemble the mainshaft without damage or incorrect assembly. (Toyota)

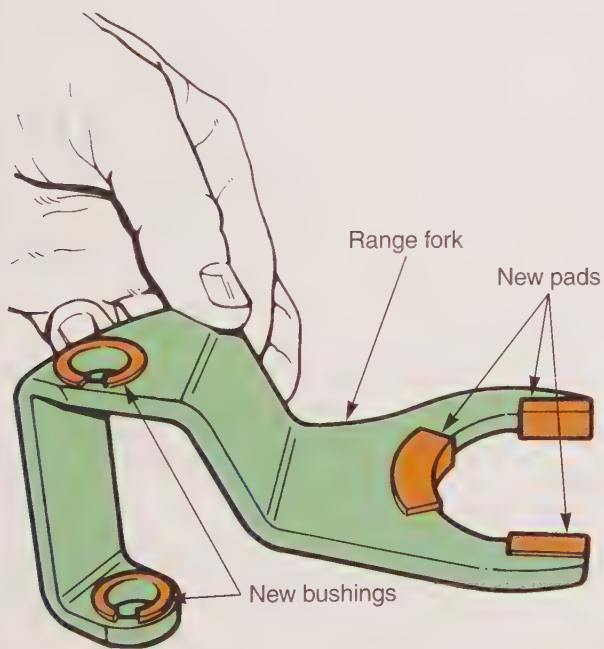
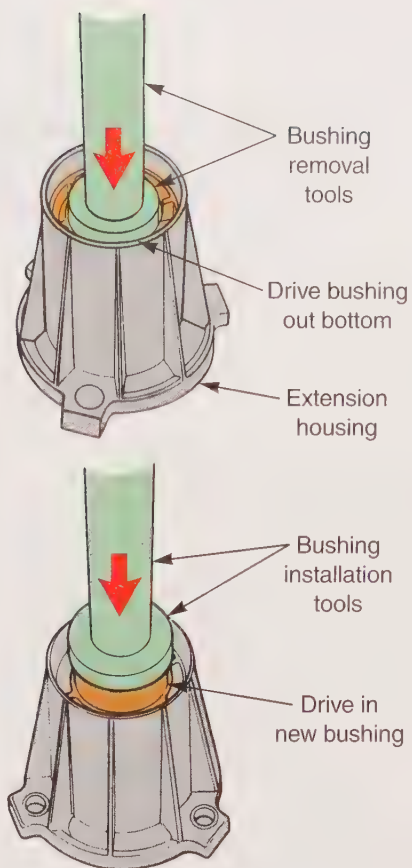


Figure 19-19. Check shift forks for wear and replace bushings or hub contact pads. Replace the entire shift fork if it is bent or worn. Seals used in areas where the shift forks or levers pass through the case should be replaced.



A

B

Figure 19-20. Before reassembling the transfer case, replace all worn bushings and seals. A—Removing and replacing an extension housing bushing. B—Installing a new seal in the extension housing.

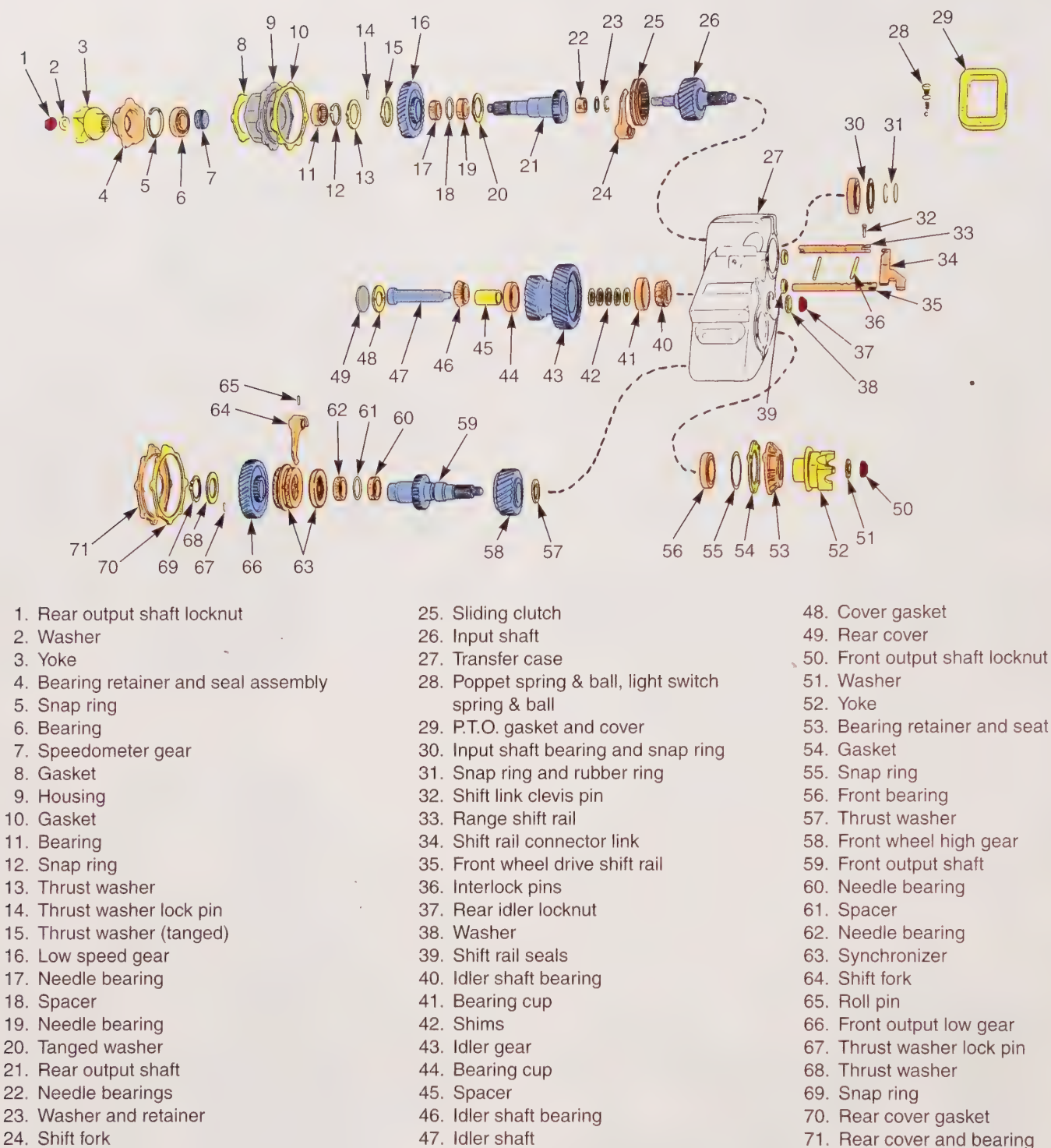


Figure 19-21. Exploded view shows the arrangement of parts in a typical one-piece transfer case. One-piece transfer cases are usually found on older four-wheel drive vehicles. (General Motors)

Figure 19-23. After installing the chain, make sure all thrust washers are installed. See **Figure 19-24**. Next, install the snap rings that hold the chain and shafts in place.

On two-piece housings, place a new gasket or an appropriate sealer, or both, on the mating surface of the front housing. Make one last check of all internal parts and install the rear housing on the front housing, **Figure 19-25**. Install and tighten the housing bolts. Then, make sure both

shafts turn. If either shaft is binding, the transfer case must be disassembled to determine the cause.

On one-piece housings, install the bearing retainers, using new gaskets. After installing the retainers, make sure the shafts turn. Do not reinstall the transfer case if the shafts are binding; correct the problem first. Adjust the bearing preload according to the manufacturer's instructions.

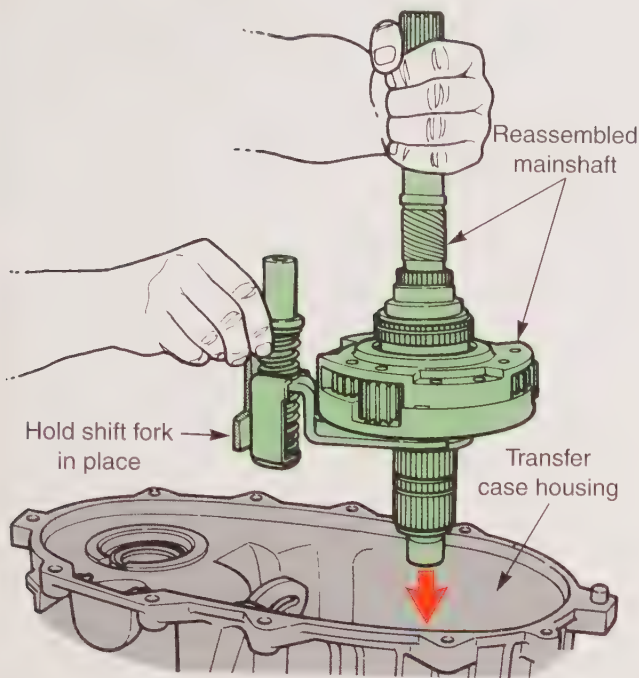


Figure 19-22. The reassembly and installation of the internal parts should be done carefully to prevent damaging parts or causing moving parts to bind. Lubricate all parts before assembly, using the same type of lubricant used in the transfer case. (Chrysler)



Figure 19-24. To ensure the proper alignment of the chain or other parts, always reinstall the thrust washers in the appropriate positions. Make sure the washers are installed facing the direction they were originally. (General Motors)

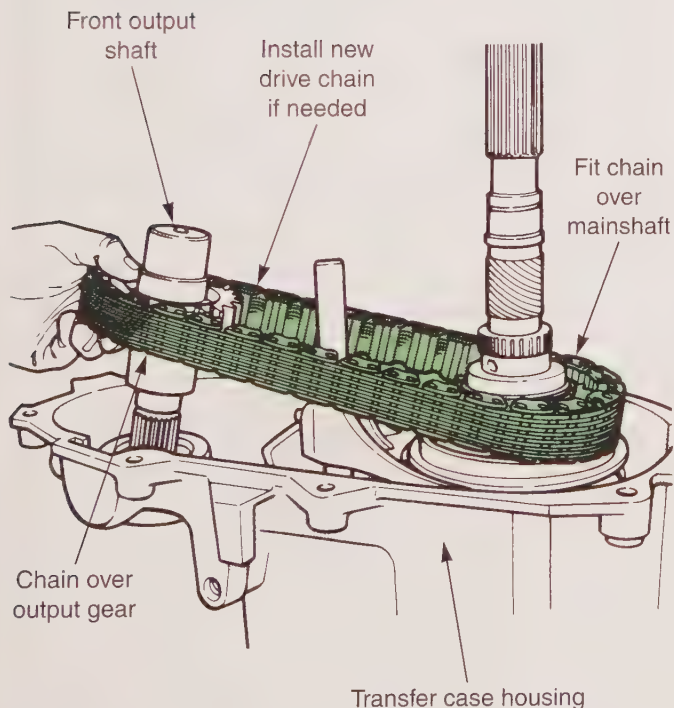


Figure 19-23. Carefully install the drive chain and sprockets. Make sure the chain is aligned with the drive sprocket and the driven sprocket, and the sprockets are correctly installed onto the shafts. (Chrysler)

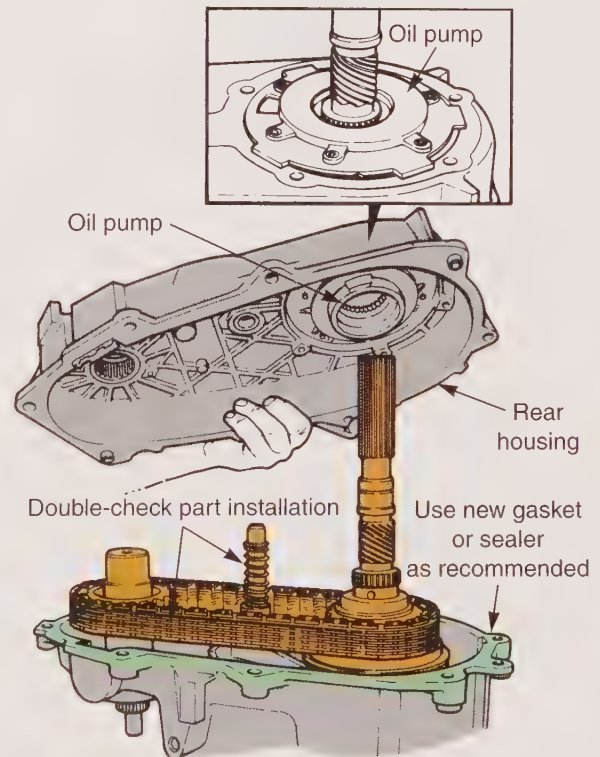


Figure 19-25. Before installing the rear half of a two-piece transfer case housing, make sure you have installed all of the internal parts. Then, install a new gasket or sealer and carefully position the rear housing over the front housing. (Chrysler)

A few transfer case manufacturers provide specifications for shaft endplay. If specifications are provided, the endplay should be measured. The procedure for checking endplay was explained in the transmission overhaul chapters. If endplay is incorrect, the rear half of the housing or the bearing retainer must be removed, and thicker or thinner thrust washers must be installed.

If hypoid drive and driven gears are used in the transfer case, they may require adjustment. The adjustment procedure is similar to that used for a ring and pinion. See **Figure 19-26**. Consult the appropriate service information for specific instructions.

Finally, install the external housing components, such as the speedometer drive gear, front and rear drive shaft yokes, electrical components, and drain and fill plugs.

Transfer Case Installation

The transfer case is installed in the reverse order of removal. Because the transfer case is heavy, exercise caution when lifting it or working around it.

1. Use a transmission jack or a jack stand to raise the transfer case to the level of the transmission (or transaxle). Slide the case into engagement with the transmission.

Work carefully to prevent damaging the splines of the transmission or the transfer case. The transmission case may have alignment lugs to make installation easier.

2. Install and tighten the bolts that secure the transfer case to the transmission. Make sure the drive shaft yokes will still turn after the transfer case is tightened.
3. If necessary, install the crossmember and rear engine mount, then remove the transmission jack.
4. Reconnect both drive shafts to the transfer case output yokes.
5. Install the transfer case shift linkage, the speedometer cable assembly, and any electrical connectors or ground straps. Install the transmission shift linkage, if removed.
6. Fill the transfer case with the proper type and amount of lubricant. Some manufacturers recommend gear oil, while others specify automatic transmission fluid. If the transmission and transfer case use the same oil, check the oil level at the transmission.
7. If necessary, install the skid plate. Then, lower the vehicle.
8. Reconnect the negative battery cable and start the engine. Road test the vehicle to make sure the linkage adjustments are correct and the transfer case operates properly. Recheck the oil level after the road test and inspect the transfer case for leaks.

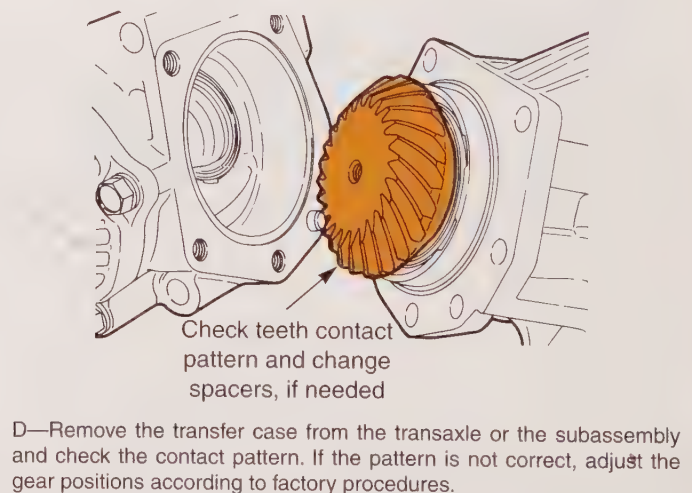
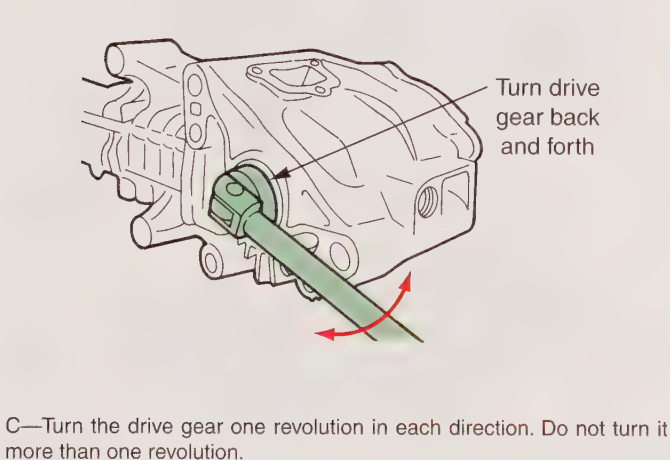
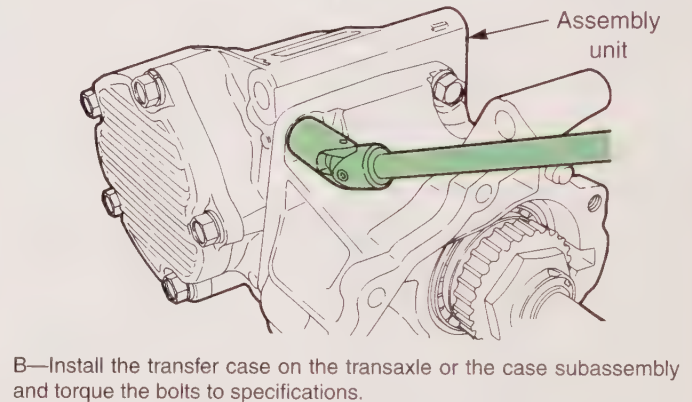
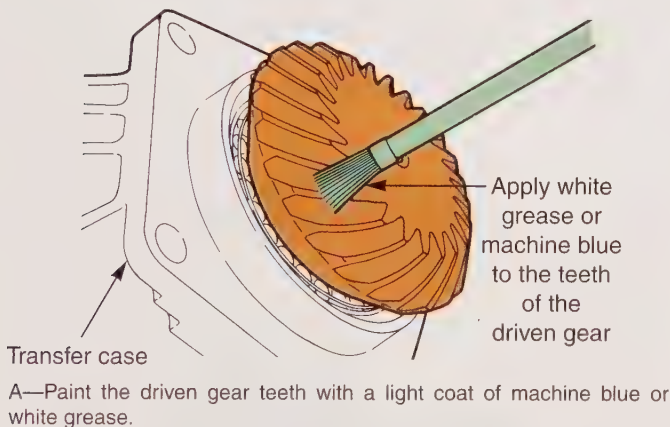


Figure 19-26. Study the procedure for checking the adjustment of hypoid gears in a transfer case. This procedure is similar to that used to check the adjustment of rear-wheel drive ring and pinion gears.

Servicing Locking Hubs

Many four-wheel drive vehicles continue to use locking hubs at the front wheels. If you are careful and refer to the proper service information, locking hubs will be relatively simple to repair.

Before disassembling a locking hub, raise the affected wheel. If applicable, shift the transfer case into two-wheel drive and place the hub in the lock position (manual model) to prevent it from turning. Remove the outer retainer cover screws. Then, remove the outer retainer and the shift cam from the hub.

Since hub space is limited, most of the other hub parts are held in place by one or more snap rings and retainer rings. Remove the snap rings and slide the retainer ring, cam follower, clutch gears, and other hub parts from the front axle housing. Some hub designs require you to remove the snap ring and then slightly turn the shaft to disengage the internal components. In certain designs, the front wheel bearing will come out with the other hub parts.



Caution: The hub parts may be heavily greased, and the snap rings may be difficult to locate. Never attempt to remove parts until you are sure all snap rings have been removed.

Place all the hub parts in order on a clean workbench. Carefully clean and inspect the parts for wear, damage, rust, and dirt. Replace all worn or damaged components. Springs should be carefully checked, since they can affect hub operation if they lose tension. Snap rings that are distorted or bent should be replaced. Always replace the seals and gaskets whenever a hub assembly is disassembled.

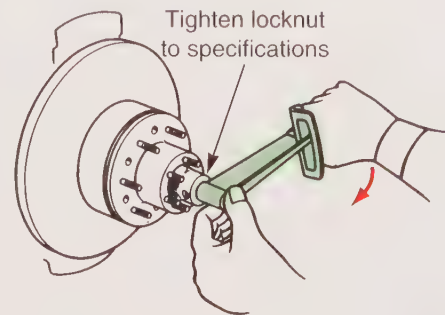
Reassemble the front axle parts in the reverse order of removal. Thoroughly grease the hub components with a proper lubricant. Reinstall the parts in the housing in the proper order, being careful to insert all snap rings in their grooves. After all parts have been reinstalled, replace the outer retainer cover and tighten the attaching screws.

After reinstalling the hub components, it may be necessary to adjust the axle preload and endplay. Typical adjustment procedures are shown in **Figure 19-27**. These adjustments are not necessary if the front wheel bearings are separate from the hub components. Add grease if the hub is equipped with a grease fitting. Road test the vehicle in the locked and unlocked positions to ensure the hub operates properly.

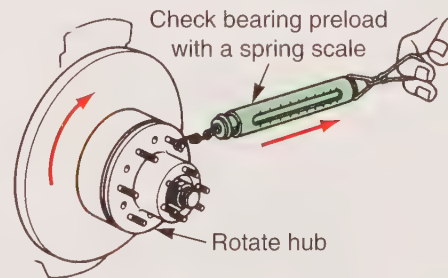
Summary

The automotive technician must be able to diagnose and repair the drive train components of four-wheel drive vehicles. Many transfer case repair techniques are similar to the procedures used when repairing manual transmissions and rear axle assemblies.

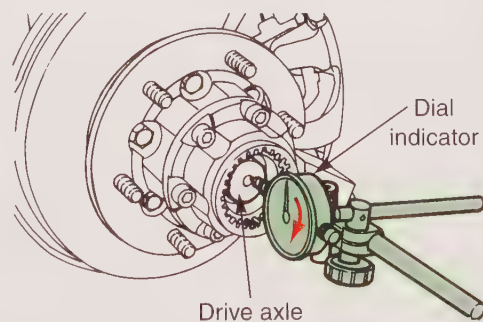
Transfer case problems can affect the operation of the entire drive train. Always make sure the problem is in the transfer case before beginning repairs. Transfer case oil leaks



A—Start by tightening the bearing attaching nut to specifications.



B—Check the bearing preload with a spring scale or torque wrench as called for in the service manual. Readjust as necessary.



C—Check and adjust the drive axle endplay. Endplay can be adjusted with shims or adjusting nuts, depending on the manufacturer. This step may not be necessary on some vehicles.

Figure 19-27. The adjustment procedure for front wheel bearings used with front locking hubs is similar to that used to adjust front wheel bearings on two-wheel drive vehicles. Refer to the specific service information to obtain the exact procedure for the vehicle you are servicing. (Toyota)

can be caused by defective seals, loose drain plugs, or loose attaching bolts. Overfilling can also cause transfer case leaks.

If the transfer case fails to drive the vehicle in any gear, the problem is usually caused by a broken or stripped internal part. If the transfer case fails to transfer power in only one gear, the problem may be in the linkage. Noises can be caused by defective internal parts or by a low oil level. Note in what range the noise occurs before attempting repairs.

If the transfer case jumps out of gear, the problem may be caused by internal part wear. In many cases, loose and misadjusted linkage can cause the transfer case to jump out of gear. A hard shifting transfer case may be caused by internal problems or by a worn or binding linkage. A defective viscous coupling may cause the transfer case to shudder.

The problems of electronically controlled transfer cases often resemble the problems that occur in mechanically operated transfer cases. Other problems are unique to the electronic control system. Many computer control system problems are called pattern failures. Problems can occur in the sensors, ECM, or shift fork motor. A commonly overlooked wiring problem is corroded or disconnected ground wires.

The easiest way to diagnose an electronic transfer case control system is with the proper scan tool. The scan tool will display trouble codes and can also be used to retrieve information from the vehicle computer. If possible, drive the vehicle and observe the applicable scan tool readings. At the same time, observe transfer case operation. Try to match the malfunction with the scan tool readings. The three ways to test electronic components are by visual checks, electrical tests, and testing by substitution.

Do not replace any electrical component without first placing the ignition switch in the *off* position and disconnecting the battery. To replace a speed sensor, remove the electrical connector. Then remove the bolt holding the sensor to the case and remove the sensor. To replace an ECM, first locate it; then disconnect the wiring connector(s) and remove the attaching fasteners.

To reprogram an ECM with a removable PROM, carefully remove the old PROM using a special tool, and then gently press the new PROM into place. An ECM in a late-model vehicle can be flash programmed—updated by erasing the old information from the computer's memory and reprogramming it with new information. The three methods used to reprogram an ECM are direct programming, indirect programming, and remote programming.

Transfer case removal is similar to manual transmission removal. Always disconnect the negative battery cable before beginning. Then, raise the vehicle and drain the oil from the transfer case.

Support the transmission and transfer case with a transmission jack. Remove all transfer case attachments, such as linkage, wiring, and braces. Then, remove the crossmember and the bolts holding the transfer case to the transmission. Slide the transfer case back from the transmission and lower it to the floor. Clean the outside of the housing before taking the transfer case apart.

Securely mount the transfer case on a workbench before beginning disassembly. Then, remove the drive shaft yokes. Remove any linkage, electrical switches, or other external transfer case parts.

Remove the internal parts of the transfer case according to the procedures outlined in the factory service manual. All gears, shafts, thrust washers, bearings, chains, and sprockets should be removed. If necessary, the differential assembly and the viscous coupling should also be removed.

After removal, clean all parts and check them for wear. Pay particular attention to gears, chains, sprockets, thrust washers, bearings, and bushings. If any parts show signs of wear, replace them. Also, replace all seals and gaskets.

Reassemble the transfer case in the reverse order of disassembly. Make sure all parts are lubricated before installation. All parts should be carefully aligned during installation. When reassembly is complete, all shafts should turn easily.

If helical drive and driven gears are used, they may require adjustment. The procedures for checking and adjusting helical gears are similar to those for the hypoid ring and drive pinion gears used on a conventional rear axle vehicle.

Position the transfer case on the transmission and reinstall all attaching bolts, linkage, and other accessories. After the transfer case is installed, fill it with the appropriate lubricant and adjust the linkages. Then, road test the vehicle to ensure the transfer case operates properly in all ranges and the shift linkage is properly adjusted.

In most cases, locking hubs can be disassembled and repaired easily. Most of the internal components are held in place by snap rings. Removing these rings will enable the internal parts to be slid off the front axle.

After disassembling the hub, check all parts for wear, damage, or corrosion. Components prone to wear include splined parts and locking cams. Replace any defective parts. Before reassembling the hub, coat all parts with the proper lubricant. After reassembling the hub, check and, if necessary, adjust the front wheel bearings and the front axle endplay.

Review Questions—Chapter 19

Answer the following questions using the information provided in this chapter.

1. When a transfer case fails to _____ properly, no power is transmitted to one or both sets of wheels.
2. If a transfer case fails to transfer power in any mode, the problem may be caused by a defective _____ or by a binding _____.
3. What can cause a transfer case to jump out of gear?
4. Many computer control system problems are called _____ failures.

5. _____ are the most common cause of electronic transfer case problems.
6. A failed _____ can also cause drivability problems.
7. Many _____ tools can be used to reprogram the vehicle computer.
8. On new OBD II vehicles, a(n) _____ connector is used to access all vehicle computer systems.
9. The _____ is a scan tool feature that records vehicle operating conditions just before and just after a malfunction occurs.
10. How do you remove a transfer case from a vehicle?
11. Blocking rings of the sliding clutch assemblies should be checked for wear on their outer _____ and inner _____.
12. The sliding clutch sleeve surfaces should be checked in areas where the _____ ride.
13. In your own words, explain how to install a transfer case.
14. When disassembling a locking hub, the hub should be in the _____ position.
15. After reinstalling hub components, you must often adjust axle _____ and _____.
3. Technician A says that electronically controlled transfer cases can develop some of the same problems that occur in mechanically operated transfer cases. Technician B says that many electronically controlled transfer case problems are pattern failures. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
4. A common speed sensor problem is _____ buildup on the sensor.
 - (A) sludge
 - (B) metal particle
 - (C) plastic particles
 - (D) carbon
5. Each of the following is a symptom of a failed transfer case ECM (computer) *except*:
 - (A) ECM illuminates the maintenance indicator light (MIL) when a sensor problem is present.
 - (B) ECM illuminates the maintenance indicator light (MIL) when there is no problem.
 - (C) ECM sets a trouble code that does not exist.
 - (D) ECM will not respond to driver range selections.

ASE-Type Questions—Chapter 19

1. Technician A says that low oil level in the transfer case is a sign of a transfer case leak. Technician B says that overfilling the transfer case can cause lubricant leaks. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
2. Each of the following statements about transfer case problems is true *except*:
 - (A) in general, a four-wheel drive vehicle that cannot move in any mode probably has a faulty transfer case.
 - (B) the transfer case must usually be removed from the vehicle to correct a no-drive condition.
 - (C) leaks from the engine or transmission are often misdiagnosed as transfer case leaks.
 - (D) normal drive train noises will seem louder when under the vehicle.



6. Which of the following parts is being installed in the above illustration?
 - (A) Aligning washers.
 - (B) Thrust washers.
 - (C) Adjusting shims.
 - (D) Silencer pads.
7. Which of the following is the *only* way to retrieve trouble codes on an OBD II computer control system?
 - (A) Connect the proper scan tool to the diagnostic connector.
 - (B) Connect two of the diagnostic connector terminals with a short wire.
 - (C) Ground one of the diagnostic connector terminals with a jumper wire.
 - (D) Probe the diagnostic connector terminals with a test light connected to the battery positive.
8. Transfer case shudder that occurs at low speed could likely be caused by _____.
 - (A) damage to the planetary gearset
 - (B) a loose drive chain
 - (C) a defective viscous coupling (if present)
 - (D) worn bearings
9. A transfer case is being removed from a vehicle. Technician A says that marking the drive shaft yokes is not necessary unless the drive shaft is being disassembled. Technician B says that the transaxle drive shafts should be left attached to the front and rear differentials if possible. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
10. Which of the following service operations can be performed without removing the transfer case from the vehicle?
 - (A) Viscous clutch replacement.
 - (B) Chain drive inspection.
 - (C) Linkage adjustment.
 - (D) Input gear replacement.
11. Technician A says that the interior of the transfer case should be thoroughly cleaned to remove sludge and metal particles. Technician B says that the interior of the transfer case should be carefully checked for small parts after disassembly is complete. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
12. Globules of silicone have been found in the oil drained from a transfer case. Technician A says that this is a sign of severe oil breakdown. Technician B says that the viscous coupling could be defective. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
13. Technician A says that some manufacturers specify gear oil for the transfer case lubricant. Technician B says that some manufacturers specify using automatic transmission fluid in the transfer case. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
14. Locking hubs on the front wheels are held in place by _____.
 - (A) a central nut and cotter pin
 - (B) snap rings
 - (C) a press fit on the spindle
 - (D) case-hardened machine screws
15. To prevent difficulty when reassembling the transfer case, the technician should _____.
 - (A) order parts before disassembly
 - (B) replace the transfer case as an assembly
 - (C) note the location of parts as the transfer case is disassembled
 - (D) apply grease profusely



Chapter 20

Noise, Vibration, and Harshness Service

After studying this chapter, you will be able to:

- ☐ Define noise, vibration, and harshness complaints.
- ☐ Identify and explain the causes of objectionable noise.
- ☐ Identify and explain the causes of objectionable vibration.
- ☐ Identify and explain the causes of objectionable harshness.
- ☐ Explain how to eliminate noise, vibration, and harshness complaints through balancing.
- ☐ Explain how to eliminate noise, vibration, and harshness complaints through damping.
- ☐ Explain how to eliminate noise, vibration, and harshness complaints through isolation/insulation.

Technical Terms

NVH

Vibration order

Harshness

Reed tachometer

Electronic vibration tester

Wheel balancer

Brake micrometer

Seven-step troubleshooting
process

Insulating

Isolating

Introduction

Drivers are no longer content with vehicles that start, run, and stop reliably. They expect their vehicles to perform all of its duties, as well as to operate smoothly and quietly. If the vehicle does not do this, the driver will complain of vibrations, noises, or harshness.

To diagnose and repair noise, vibration, and harshness complaints, the technician must know what causes the problem and how it is eliminated or isolated from the passenger compartment. This chapter identifies the sources of noise, vibration, and harshness. It also explains how to isolate these problems and eliminate them.

Noise, Vibration, and Harshness (NVH)

Drivers may complain of vibrations that can be felt in the steering wheel or seats or, sometimes, in the brake pedal or the door panels. Other drivers may complain of various kinds of noises, such as whining or singing sounds, from the drive train or dashboard. Sometimes, the driver will complain of jarring or other impact sensations, which are often accompanied by noise. These complaints are referred to as NVH complaints. **NVH** is the abbreviation for noise, vibration, and harshness.

It is important that the drive train technician understand exactly what causes various NVH complaints. **Figure 20-1** shows some typical sources of noise, vibration, and harshness.

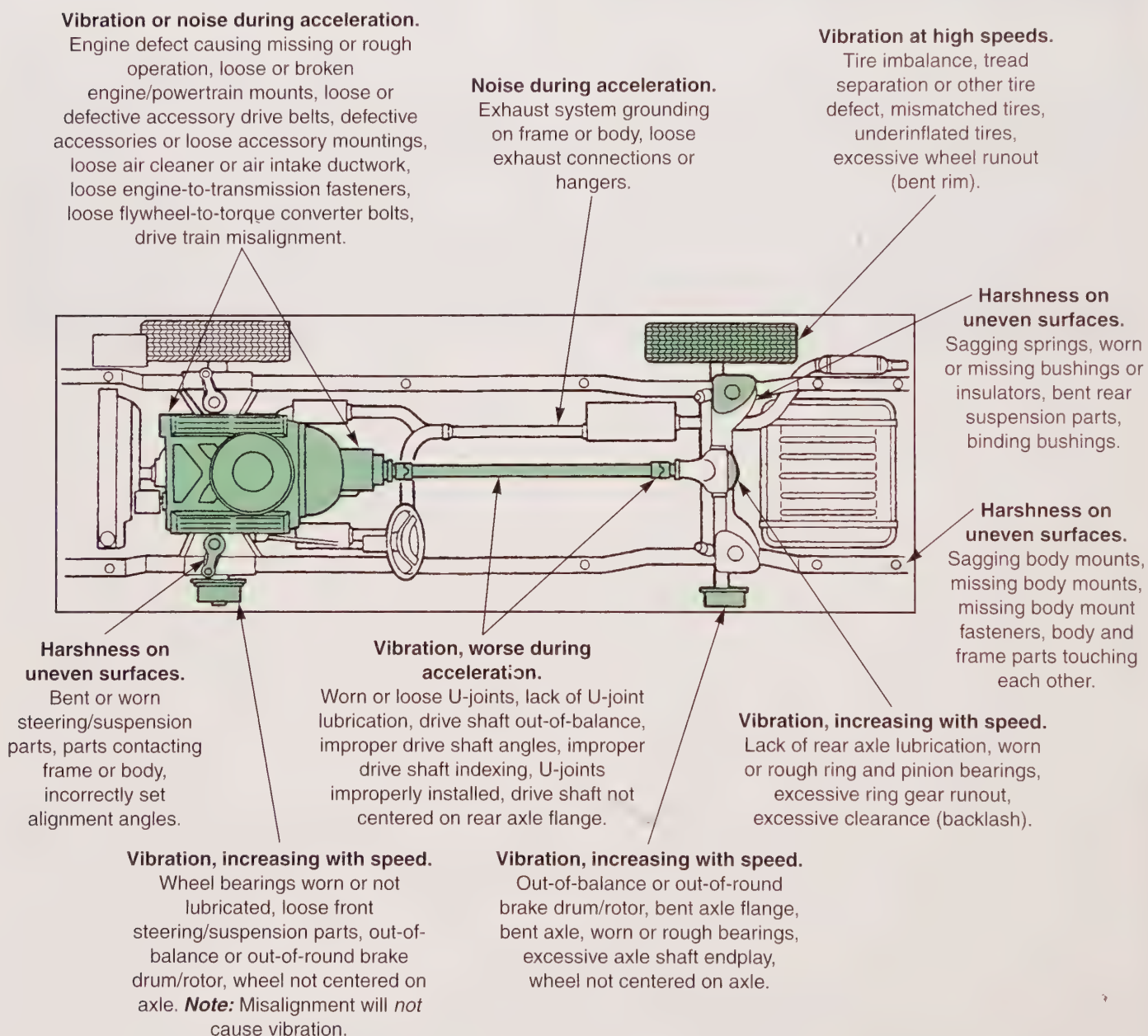


Figure 20-1. Some typical sources of noise, vibrations, and harshness. These are not the only possible transmission sources.

and harshness. The types of NVH and their sources are discussed in the following sections. Be sure to read the following sections before proceeding to the diagnosis and corrections sections.

Vibration and Noise

Vibration is a repetitive motion of a rotating part. There are two kinds of vibration, axial and radial. Axial vibration is a lengthwise, or back-and-forth, movement of the shaft along its rotational axis. Axial vibration occurs only when the moving parts are very worn or loose. Parts this loose will usually cause clunking or rattling noise before they cause vibration. Radial vibration is a side-to-side movement of a rotating part along its rotational axis. Radial vibration is the most common cause of vibration in automotive drive shafts and CV axles. Causes of radial vibration include parts that are out of balance or bent. Incorrect angles between moving shafts may cause the connecting CV or U-joints to vibrate. Incorrect angles are much more likely to cause vibration of a drive shaft with U-joints than one with CV joints. Axial and radial vibration were covered in Chapter 13.

Drive shaft vibrations occur whenever the vehicle is moving and the vibration pulses occur at regular intervals. The vibrations are measured in terms of frequency and amplitude. Frequency is how often a vibration cycle occurs during a set time, and varies in direct proportion to drive shaft speed. Amplitude is a measure of the strength of a vibration.

Vibration order is the number of times a vibration occurs during one revolution of the rotating part. A first order vibration would occur one time per revolution. A second order vibration would occur twice per revolution.

Theoretically, there could be any number of orders of vibration. In practice, however, most vibrations are first order and are almost always caused by an out-of-balance rotating part. Even when the part has two unbalanced areas, their forces combine to result in a first order vibration. This vibration may be more noticeable than a vibration caused by a single unbalanced area, but it will still be a first order vibration.

A vibration does not become a problem to the vehicle's owner unless it is felt. To be felt, the vibration caused by any source must reach the driver or passengers through a transfer path to a responder. For example, a vibration caused by an out-of-balance CV axle is transmitted through the steering knuckle, to the steering linkage, and to the steering wheel. The steering knuckle and steering linkage make up the transfer path, and the steering wheel is the responder. The driver feels the wheel vibrating but does not know the source. A vibration can also be caused by a worn and loose rear U-joint. The vibration is transmitted through the rear axle, rear suspension, and vehicle body to the car seat. The driver feels vibration in the seat but, again, does not know what is causing it.

Most vibrations produced by a vehicle are above or below the normal range of human hearing. However, if

a vibration happens to fall within the human hearing range, it is perceived as a noise. Noise is always caused by vibration. High-pitched vibrations cause moans or whines from gears or tires. Vibration in a dashboard part may also cause a noise. The actual cause of the noise may be a loose attaching screw, which allows the dashboard component to vibrate within the range of human hearing.

Sources of Vibration and Noise

Every moving part in the engine, transmission, and drive train produces some vibration. Other vehicle systems, such as the heater and air conditioner, power steering, and alternator, have moving parts that also produce vibration. On occasion, the vibration can lead to noise. Typical sources of excessive vibration include the following:

- ☐ Engine cylinder defect (fouled plug, clogged injector, or burned valve).
- ☐ Engine balance defect (vibration damper slipped, crankshaft bent or unbalanced).
- ☐ Broken engine or transmission/transaxle mounts or loose mount fasteners.
- ☐ Loose transmission/transaxle-to-engine mounting bolts.
- ☐ Loose or cracked flywheel (ring gear) or missing balance weights.
- ☐ Unbalanced clutch assembly.
- ☐ Worn out or greasy clutch plate.
- ☐ Cracked transmission/transaxle case.
- ☐ Worn or damaged transmission or transaxle bearings or gears.
- ☐ Bent transmission or transaxle internal shafts.
- ☐ Bent drive shaft or CV axle shaft(s).
- ☐ Worn U-joints or CV joints.
- ☐ Exhaust component contacting the vehicle body or frame.
- ☐ Loose or worn wheel bearings.
- ☐ Worn or unbalanced tires.
- ☐ Bent or cracked wheel rims.
- ☐ Dragging brakes or warped rotors/drums.
- ☐ Loose suspension or steering parts.

Harshness

Harshness is a condition usually described as the action of a vehicle component that is harder or more severe than normal. An example of harshness is the hard ride of a vehicle with excessive tire pressure or stiff shock absorbers. Another example of harshness is impact caused by excess play in moving drive train parts such as a loose CV or U-joint. Harshness is often accompanied by clunking or thumping noises, usually described as a clunk or thump.

Sources of Harshness

Harshness is usually the result of defects in the vehicle suspension and steering systems that prevent them from properly controlling vehicle movement. Other harshness complaints are caused by a lack of flexibility in a part that is supposed to flex and absorb vibrations. Another harshness cause is excessive play in drive shaft assembly parts. Some possible causes of harshness include the following:

- ☐ Loose suspension or steering fasteners.
- ☐ Defective shock absorbers or struts.
- ☐ Faulty springs or torsion bars.
- ☐ Worn U-joints or CV joints.
- ☐ Loose wheel bearings.
- ☐ Cracked transmission/transaxle case or loose transmission/transaxle to engine mounting bolts.
- ☐ Broken engine or transmission/transaxle mounts or loose mount fasteners.
- ☐ Exhaust component contacting the vehicle body or frame.
- ☐ Overinflated tires.
- ☐ Incorrect or defective tires.
- ☐ Bent or cracked wheel rims.
- ☐ Worn out or misadjusted brakes or warped rotors/drums.

Any one or a combination of these defects may be present on the vehicle. Sometimes an obvious defect may not be the cause, even though it may need correction. For this reason, the technician should carefully isolate and determine the exact cause of the problem.

Reducing NVH

Vehicle manufacturers use three methods to reduce NVH:

- ☐ Carefully balancing and fitting moving parts.
- ☐ Damping vibration and noise with weights on drive train parts.
- ☐ Insulating the body and passenger compartment from moving parts.

All vehicle manufacturers use variations of these methods. Rotating engine and drive train components are carefully balanced at the factory. To ensure that enough oil reaches between moving surfaces to absorb shocks, moving parts are pressure and splash lubricated. Transmission and differential gears are fitted to ensure excessive clearance will not cause noises when speed and direction change. Weights are sometimes installed on moving parts to reduce NVH. An example is the vibration damper placed on the crankshaft of every engine. Many vehicles also have dampening weights on the drive shaft or CV axles. Other manufacturers place dampening devices on the transmission extension housing.

In addition to insulating the body and passenger compartment, vehicle designers must ensure objectionable NVH does not reach the seats, steering wheel, or brake pedal. The seat mounting system is designed to absorb and

dampen vibrations from the floor pan. Flexible couplers are used in the upper and lower steering column, and hydraulic dampers may be installed on the steering linkage. Brake rotors and drums are machined in such a way that they do not cause excessive vibration when contacted by the pads or shoes. The brake hydraulic system absorbs some small vibrations caused by the brake friction components.

Diagnosing NVH Complaints

No matter how carefully the vehicle is designed, slight amounts of NVH will always be created and transferred to the passenger compartment. Often a defective part or system creates enough noise, vibration, or harshness to cause an NVH complaint.

The drive train technician is often called on to diagnose NVH complaints. To diagnose an NVH complaint, the technician must know the possible sources of NVH, as well as how they are transmitted.

NVH Test Equipment

To diagnose NVH problems, special test equipment and tools will be needed. Some of this equipment, such as micrometers, dial indicators, and scan tools, were discussed in Chapter 3. The technician will find other equipment useful when diagnosing NVH problems. These pieces of equipment are discussed in the next few paragraphs.

Vibration tester

A vibration tester is useful in isolating vibration sources and pinpointing the exact kind of vibration. There are two main classes of vibration testers, the reed tachometer and the electronic vibration tester.

The **reed tachometer** is a mechanical device with rows of small reeds. The reeds are arranged so that each reed vibrates at a slightly higher frequency than the reed to the left. This allows the technician to observe vibrations as their frequency changes. The tachometer face contains two rows of reeds, one for vibrations of 10–20 Hertz (cycles per second) and the other for vibrations of 20–80 Hertz. The reed tachometer cannot be used to isolate vibrations when their frequencies are above 80 Hertz or below 10 Hertz. However, most automotive vibrations and vibration related noises occur within the 20–80 Hertz range.

To use the reed tachometer, place it as close to the source of the vibration as possible. Then observe the tachometer under various load and speed conditions. Changes in load and speed should affect the frequency as read on the tachometer.

Electronic vibration testers are also used to locate the source of vibration, **Figure 20-2**. Electronic vibration testers resemble scan tools, and many are equipped with a programming cartridge. Instead of being placed directly on a suspected vibrating part, electronic vibration testers have a separate vibration sensor. The vibration sensor is a

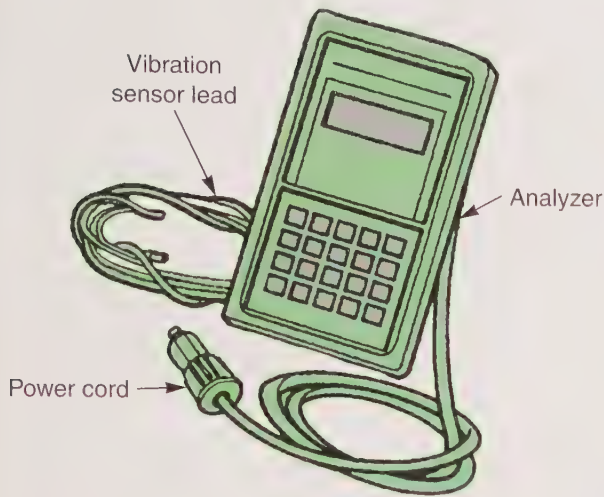


Figure 20-2. This is an electronic vibration analyzer produced by one manufacturer. The analyzer provides the technician with information on the frequency and strength of a vibration.

movement-sensitive crystal similar to those used in engine knock sensors. The sensor is attached to the tester by an electrical cord. Plugging a 12-volt adapter into the cigarette lighter receptacle energizes the tester. The advantage of this tester is that it can be used while driving the vehicle, and the tester screen can be placed where it is easily visible, no matter where the sensor is placed. This allows for a more accurate vibration diagnosis. The electronic vibration testers will also work over a wider range of frequencies.

To use the electronic vibration tester, place the vibration sensor as close as possible to the source of vibration. Start the tester by plugging in the 12-volt adapter, and then select the proper display screen. Observe the tester display screen while changing engine and vehicle load and speed conditions. Changes in load and speed should affect the frequency displayed by the tester.

Wheel balancer

A **wheel balancer** can be used to spin wheel and tire assemblies and brake drums to check for imbalance. **Figure 20-3** shows a typical electronic wheel balancer. Use of the wheel balancer will be discussed later in this chapter.

Brake micrometer

A **brake micrometer** is a specialized micrometer used to check brake drums and rotors for proper thickness and out-of-round conditions. The two types of brake micrometer are the rotor micrometer and the drum micrometer. How these micrometers are used will be covered later in this chapter.

The Seven-Step Troubleshooting Process

The **seven-step troubleshooting process** enables the technician to quickly isolate transmission problems. This process uses seven logical steps to reach a conclusion about what is wrong. The seven-step process works to



Figure 20-3. A modern tire balancer will quickly locate an out-of-balance tire. Modern balancers have a cover to protect the technician from any debris that might fly from the tire.

troubleshoot any NVH problem. **Figure 20-4** shows the seven-step process. Refer to this figure as you read the descriptions presented in the following sections.

You may think that seven steps are too many to bother with. However, the secret to successful diagnosis is checking, rechecking, and checking again until you are absolutely certain you have found the cause of the problem. The seven-step process is designed to do just that.

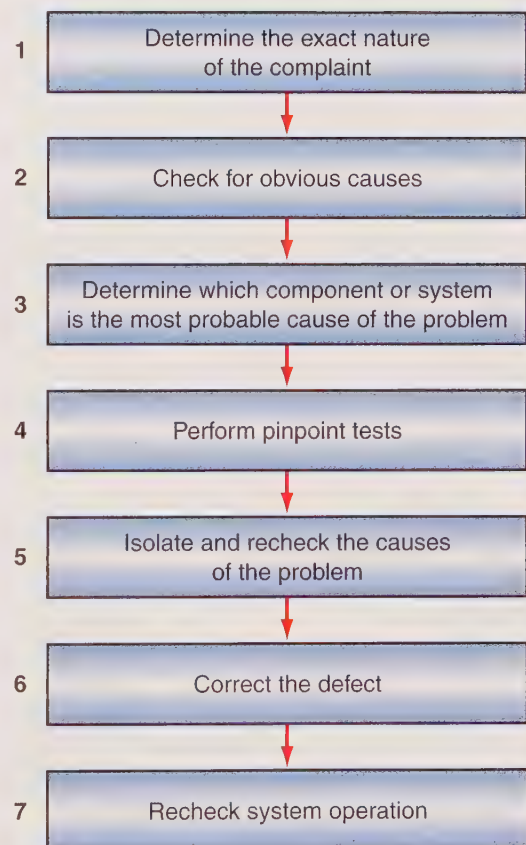


Figure 20-4. Following the seven-step process shown in this flowchart will save time in diagnosing an NVH problem.

Step 1—Determine the exact nature of the complaint

While it is pointless to begin work on an NVH problem until the owner's complaint has been identified and verified, this step is probably the one that is most often overlooked. To determine the exact nature of the NVH problem, begin by asking the vehicle driver to describe what the vehicle is doing. Listen carefully to the driver's description, as this may give you significant clues to the exact problem. Sometimes the driver's description must be interpreted. For instance, the driver may describe a vibration as a noise, since he or she is hearing a noise. Remember that vibrations are the root cause of all noises.

At this point, you may be ready to do a road test. Do not be surprised if the actual NVH problem does not match the driver's description. Remember that the average driver is not a technician, and he or she may misinterpret the symptoms. For example, the driver may describe the vibration as happening all the time. Driving the vehicle reveals that the vibration occurs only when the brakes are used. Without a road test, you would have been looking for drive train or suspension/steering problems, instead of concentrating on the brake system.

Sometimes, the driver may mistake a normal condition for a problem. A driver may have traded in an older rear-wheel drive car for a smaller front-wheel drive car or an SUV. After driving the new vehicle, he or she may decide that the increased noise levels normal in a front-wheel drive system or SUV body indicate a problem. Your task in this situation is not to work on the vehicle, but to educate the driver.

After considering all the information you have gathered from the driver and the road test, you can now determine the exact nature of the NVH complaint. Once you have established the exact complaint, proceed to the next step.

Step 2—Check for obvious causes

If the road test indicates a problem, always check for obvious causes. Checking the simple things first can save a lot of time. Look for loose bolts or obviously bent or worn parts. Check for debris on the drive shaft(s), worn CV or U-joints, and loose drive train fasteners. Also check that the engine has no driveability-related problems, such as a miss caused by a defective plug or fuel injector. Engine problems often result in NVH complaints. If you do locate any obvious problems, correct them and recheck the vehicle as outlined. If you did not locate any obvious causes of the NVH complaint, proceed to the next step.

Step 3—Determine which component or system is the most probable cause of the problem

In this step, check the components and systems that could cause the problem. Combine the information that you gained in Step 1 with the knowledge of how vibrations develop and are transmitted. Using this information and knowledge in a logical manner will lead you to the vehicle

components or systems that are most likely to cause the problem. When called for, use the test equipment discussed above to isolate the source of vibration or other cause of the problem. A troubleshooting worksheet is useful for determining the frequency and order of a vibration or noise. The information on the worksheet can then be used to determine the most logical vehicle part or area that could be causing the problem.

Whenever possible, review a vehicle's service history. Previous service records may contain information needed to determine whether a similar problem was encountered in the past and, if so, what was done to correct it. Service records can also reveal past repairs that could impact current vehicle operation. A lack of service records may be an indication that a problem was caused by a failure to perform needed maintenance.

Once you have determined the most likely cause of the problem, proceed to the next step. The next step will either confirm your diagnosis or indicate that you must begin again.

Step 4—Perform pinpoint testing

Once you have determined what could be causing the problem, you must begin to check these systems and parts. This process involves testing major parts and system. It may be necessary to disassemble some components to determine their condition. After every system has been checked and a probable source of the problem found, proceed to the next step.

Step 5—Isolate and recheck the causes of the problem

In this step, you should recheck to make absolutely sure the defect you uncovered in the last step is the real cause of the problem. Always recheck the suspect part using the proper test equipment and procedures. If your testing causes you to reach the same conclusions as in the last step, you have probably found the problem.

Step 6—Correct the defect

In this step, you make the necessary repairs to restore the unit to proper operation. Defect correction ranges from simple things, such as tightening a fastener, to completely overhauling a transmission or transaxle. General procedures for correcting NVH problems are covered in the next section of this chapter. Detailed procedures for correcting various drive shaft assembly defects were covered in previous chapters.

Step 7—Recheck system operation

In this step, you recheck the vehicle to make sure the problem has been corrected. This usually means a road test to ensure the NVH problem is gone. Always recheck vehicle operation, no matter how obvious the fix appears to be.

The Importance of Follow-up

Always try to think about what you have discovered and how it will affect the operation of the vehicle in the future. This may lead you to discover hidden problems that should be corrected to keep the original problem from reoccurring. For instance, if the original problem was a vibration on take-off caused by an oil-saturated clutch plate, you will need to determine what caused the clutch plate to become oily. In this case, you will want to find out if the rear main seal or another engine seal is leaking oil onto the clutch. If so, you must inform the owner that the new clutch plate will be ruined if the oil leak is not corrected. Even if the customer decides not to have the leak fixed, this will prevent misunderstandings when the problem reoccurs.

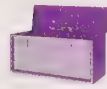
After repairs are completed but before returning the vehicle to the customer, check that parts that could easily be overlooked, such as wheel covers, have been reinstalled on the vehicle. Just before delivery, remove steering wheel covers, paper floor mats, upholstery covers, and any other vehicle protection items. If the carpet, upholstery, or steering wheel has been soiled, remove the material with a nondamaging cleaning solution.

NVH Complaint Correction

Once the NVH problem has been located, it must be corrected. The best way to correct an NVH complaint is to eliminate its source. There are many methods of eliminating NVH sources. Some research may be necessary to determine the proper method. Vibration can often be reduced if the rotating part is balanced. Sometimes weights can be added to damp out the vibration source. Sometimes a part is bent and should be replaced. Harshness can be reduced or eliminated by ensuring that the clearances between all moving parts are correct and that defective steering, suspension, and drive shaft assembly parts are replaced. If the source of vibration or harshness cannot be eliminated, it may be possible to isolate the source from the driver and passengers.

Drive Shaft and CV Axle Vibration Correction

Since drive shafts and CV axles are common sources of NVH problems, manufacturers carefully balance all axles and set driveline angles. A drive shaft or CV axle that has not been damaged will stay balanced for the life of the vehicle. Since drive shaft and CV axle alignment depends on many factors, such as engine mount and suspension condition, alignment may change over time. Driveline assembly vibrations can be felt in the steering wheel, brake pedal, or vehicle body. As a first step, make sure the vibration is not caused by problems in the tires, wheels, or brake system.



Note: On rear-wheel drive vehicles the drive shaft turns at higher speeds than the wheels, and as a result, drive shaft vibration will occur at a higher frequency than wheel- and tire-produced vibration. Front-wheel drive CV axles turn at the same speed as the wheels, and wheel and axle vibration will occur at the same frequency.

Worn U-joints or CV joints, especially the front joint on a rear-wheel drive vehicle, will cause a vibration when the vehicle is accelerated between 30 and 40 mph (48 and 64 km/h). Other causes of vibration are dirt or undercoating stuck to the drive shaft, missing balance weights, or a bent shaft. Other possible causes of vibration are a loose fit between drive shaft yokes and U-joint bearing cups, a broken lug on one of the yokes, a defective center support bearing (on front- or rear-wheel drive vehicles with two-piece drive shafts), or a worn slip yoke or transmission extension bushing.

Drive shaft alignment and worn flexible joints can be corrected by adjustment and replacing worn parts. If the shaft itself is out-of-balance due to wear or damage, it is usually replaced. The center tube of some drive shafts can be replaced. This is often done on older vehicles when a new drive shaft cannot be obtained. It is usually quicker and cheaper to replace the entire drive shaft of a newer vehicle. Sometimes a dampening weight has been removed from the shaft. Weights can be installed to eliminate the NVH complaint. See **Figure 20-5**. Chapter 13 contains information on balancing the drive shaft and checking U-joint angles. CV axle information is contained in Chapter 15. Note that there is no procedure for checking and adjusting CV axle angles. CV joints can compensate for minor CV axle misalignment.

Tire and Rim Vibration Correction

Many NVH complaints are the result of tire and rim problems. While tires and rims are usually not considered part of the drive train, the drive train technician often

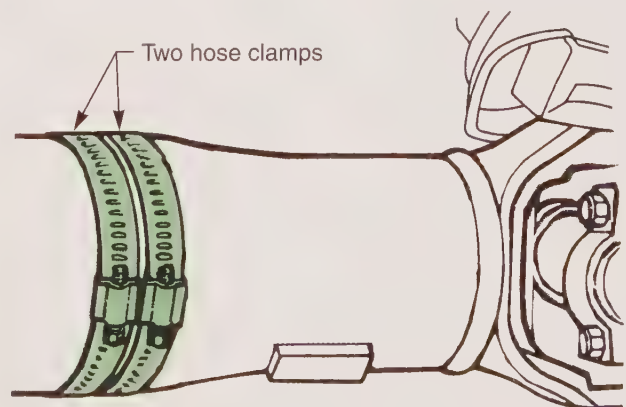


Figure 20-5. Hose clamps are installed on a drive shaft to eliminate an unbalanced condition. (Chrysler)

encounters a defective tire or wheel while searching for what appears to be a drive train NVH problem. The following sections give a general description of how to locate and correct tire and rim problems.

Tire balance

Tire balance can be checked using a tire balance machine. To check tire balance, remove the tire and wheel assembly from the vehicle and check it for damage. Remove any stones imbedded in the tread. Then, install the tire and rim on the balancer shaft. Set the tire size and wheel rim dimensions at the wheel balancer's control panel. Press the start button. A motor spins the tire and wheel assembly, while the sensors check balance. Observe the tire as it spins to check for an out-of-round condition. Slight variations in roundness is normal, but a large amount of runout (side-to-side variations from true rotation) indicates a rim or tire defect. Tire condition and rim runout checking are discussed later in this section.

The needed amount of weights and where they should be placed will be displayed on the control panel. Add weight as necessary, and then push the start button to recheck. If the control panel indicates different weights and positions after the new weights are added, the tire cannot be balanced. The tire is therefore defective, or the wheel rim is bent.

Tire condition

To check tire condition, always check air pressure first. Low and uneven tire pressures often cause vehicle-handling problems. If tire pressure is low, check for leaks at the tread, sidewalls, rim, and tire valve. The usual method of checking for leaks is to overinflate the tire and submerge it in a water trough. Bubbles will rise through the water when the leak is submerged. Another method is to spread soap solution on the suspected areas of the tire. The leaking area will show up as foam or bubbles.

Sometimes a tire will have obvious damage, such as the tread separation. However, a tread separation will not always be visible. Often a tire with tread separation can be balanced on an off-car tire balancer but vibrates when reinstalled on the vehicle. To check for hidden tread separation, move the tire to a different axle. For instance, if the tire is on the front, move it to the rear. If the vibration now feels different when the vehicle is driven, the tire is defective.

Other common and easily observable tire problems are excessive or uneven tread wear and sidewall damage. See **Figure 20-6** and **Figure 20-7**. Uneven tread wear often causes a "singing" noise and is common on the rear wheels of front-wheel drive vehicles. Corrections for these problems are to replace the tire and align the suspension.

Sometimes a tire will cause waddle (side-to-side movement of the steering wheel), with no obvious signs of tread separation. The simplest checking method is to move the suspected tire to the rear or temporarily replace it with another tire. If the waddle stops, the tire is defective and should be replaced.

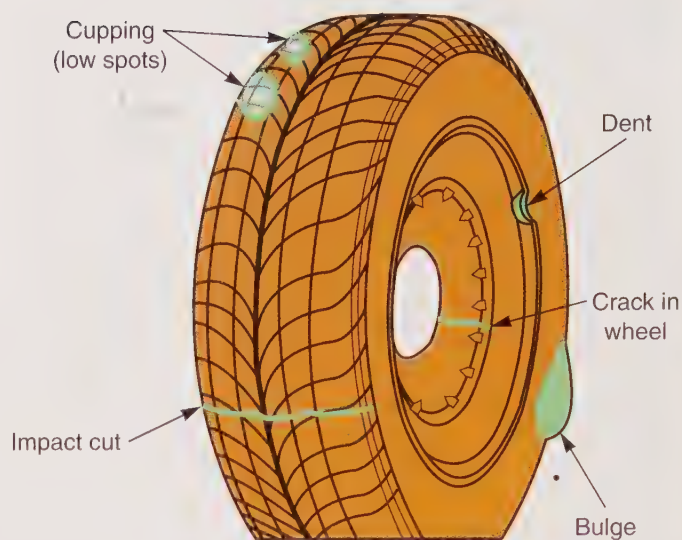


Figure 20-6. A tire and wheel illustrating common damage. Check all tires and wheels closely before proceeding with alignment.

Wheel runout

Excessive wheel runout can contribute to an NVH complaint. Begin by checking the wheel for obvious damage. Slight bends in the rim can sometimes be corrected, but if the rim is badly bent, the wheel should be discarded. Also check the center section of the wheel for cracks. Take a close look at the mounting holes, since small cracks at this location can expand quickly to cause total failure of the wheel. Cracked wheels are sometimes the source of mysterious front-end noises.

If the wheel has no obvious damage, but appears to be the source of a vibration problem, check it for runout using a dial indicator. To do this, remove the tire and mount the wheel on a non-driving wheel or on a tire balance machine. Then attach a dial indicator to the rim as shown in **Figure 20-8**. Set the dial indicator to check lateral (side-to-side) runout first, since this is the most common runout problem. The pointer should just touch the rim at

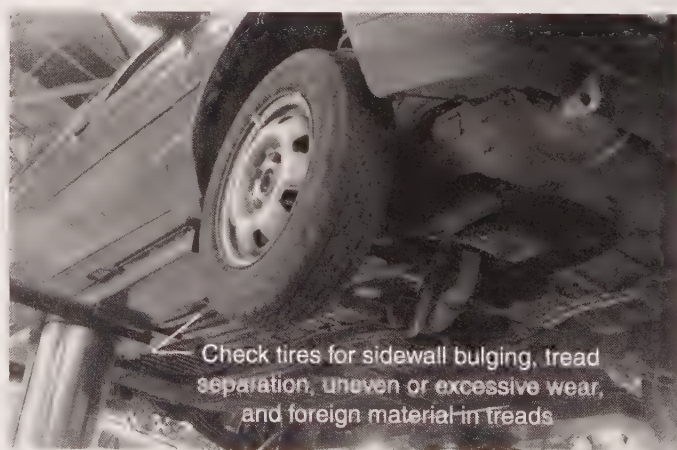


Figure 20-7. Carefully check each tire for defects. This is best done with the tire off the ground and raised to provide easy access.

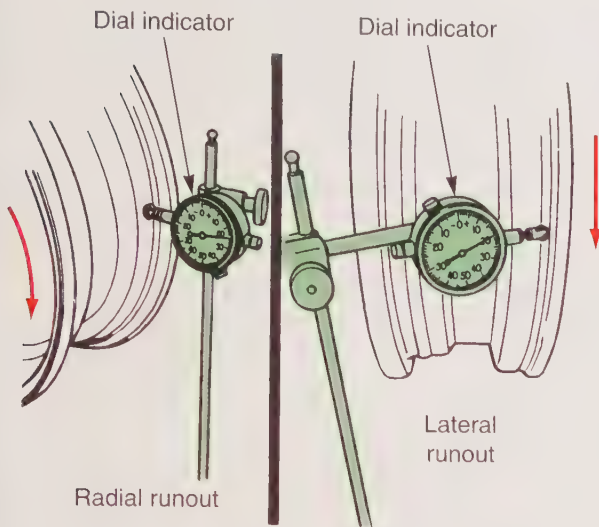
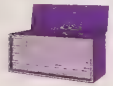


Figure 20-8. A dial indicator is needed to check wheel rim runout. Remember to check both radial and axial runout. (Chrysler)

the place indicated. Slowly rotate the rim and observe the smallest and largest readings. Subtract the smaller reading from the larger to get the lateral runout. If lateral runout is excessive, replace the rim. If lateral runout is within specifications, set the dial indicator to check radial (up and down) runout as shown in **Figure 20-8**. Again, slowly rotate the rim and observe the smallest and largest readings. Subtract the smaller reading from the larger to get the radial runout. If the runout is not within specifications, replace the rim.



Note: It is almost impossible to straighten a badly bent rim precisely enough to correct a runout problem. Attempting to straighten the rim may further weaken it, causing failure when the vehicle is being driven.

Checking steering and suspension parts

Loose steering and suspension parts can cause vibrations. These vibrations may cause oscillations in the tire and wheel assembly. Steering and suspension vibrations are often mistaken for drive train or tire vibrations. To check the steering and suspension, raise the wheel from the ground and shake it as shown in **Figure 20-9**. Grasp the wheel at the top and bottom and attempt to move the wheel in and out. Then, grasp the wheel at the front and rear and attempt to move the wheel in and out. Any looseness in the wheel indicates a worn part. The general rules about excessive wheel looseness are:

- ❑ Looseness when the wheel is shaken while holding it at the top and bottom indicates a loose suspension part.
- ❑ Looseness when the wheel is shaken while holding it at the front and rear indicates a loose steering part.
- ❑ Looseness at every point when the wheel is shaken indicates loose wheel bearings.



Figure 20-9. Shaking the tires is the easiest way to check steering and suspension parts for looseness. The problem can be pinpointed more accurately by noticing which direction produces the most movement.

If any looseness is found, proceed to isolate the defective component and correct it. Do not ignore loose steering and suspension parts, even if you decide they are not the source of vibration. Defective steering and suspension parts can fail and cause a complete loss of steering.



Note: Incorrect alignment is almost never the cause of vibration. Incorrect steering and suspension alignment usually causes pulling to one side, poor steering wheel return, or uneven tire wear.

Brake Vibration Correction

The brake system parts often create NVH problems that are similar to drive train NVH conditions. It is often necessary to isolate and diagnose brake problems as part of drive train NVH service. There is no way to cover all aspects of brake diagnosis in this chapter. The following sections, however, give a brief description of how to check for the most common brake related causes of NVH.

Out-of-round rotors or drums

Out-of-round rotors or drums can cause severe vibration when the brakes are applied. Some noises during braking can also be caused by out-of-round drums, warped rotors, or variations in rotor thickness. Severely warped rotors may cause vibration even when the brakes are not being applied. When an out-of-round condition is suspected, begin by checking the drums for damage, out-of-round or taper, and proper thickness. Check rotors for excessive runout (warping), proper thickness, and thickness variations.

See **Figure 20-10**. These checks are explained in the following sections. Normal braking surface wear patterns are small scratches and a slight polishing of the braking surfaces. They do not greatly affect braking. Scoring or grooving on the braking surface must be removed by machining (turning) the surfaces. Heat checking and bluing can be removed by turning or by replacing the drum or rotor, **Figure 20-11**. Check with your instructor concerning brake drum and rotor turning and the proper use of brake lathes.

Rotor thickness

To check rotor thickness, obtain a rotor micrometer. Before checking thickness, calibrate the micrometer if necessary. Then install the micrometer over the rotor. If the rotor is grooved, place the point of the micrometer in the deepest groove. Then read the thickness on the micrometer



Figure 20-10. Check the rotor for problems that could result in vibration. Most brake-related vibration occurs while the brakes are being applied. Occasionally, a severely warped rotor can contact the pads and cause vibration when the brakes are not being used.

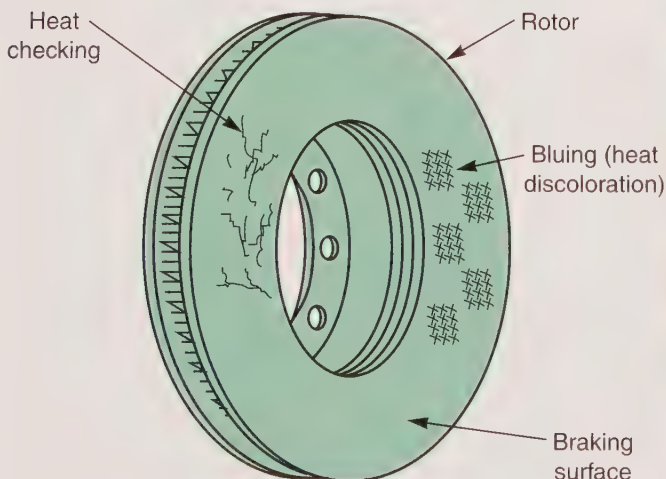


Figure 20-11. This illustrates heat checking and bluing caused by heavy braking or severe service. A heat-checked rotor should be replaced.

and compare it to the specified minimum thickness. The thickness should be more than the minimum if the rotor will not be turned. If the rotor will be turned, it must be thick enough to allow some metal to be removed during the turning process and still be at the minimum thickness.

Turn the rotor about one-quarter turn and check the thickness again. Repeat this process to check at least four places on the rotor. If the thickness variation between parts of the rotor is more than about .01" (25 mm), the rotor should be turned to prevent brake pulsation.

A dial indicator is needed to check rotors for excessive runout or warping. Before checking runout, eliminate any looseness in the rotor and hub assembly. If the rotor is separate from the hub, install at least three of the wheel bolts onto the lugs on the reverse direction. The flat (non-tapered) side of the nuts should contact the rotor. Lightly tighten the nuts until there is no play between the rotor and hub. If the rotor is integral with the hub, check that there is no play in the wheel bearings. If play is evident, tighten the wheel bearings until all play is removed (tapered roller bearings) or replace the bearings (ball and flat roller bearings). Then place the dial indicator over the rotor so that the pointer contacts the rotor about two-thirds of the way to the edge of the braking surface. The pointer should be on a flat spot, not over any grooves. Then, tighten the mounting clamp. A typical dial indicator installation is shown in **Figure 20-12**. Set the indicator's dial to zero. Turn the rotor slowly and observe the movement of the dial indicator. If the dial indicator shows a runout of more than about .01" (25 mm), the rotor should be turned or replaced. Mark the point of maximum runout for later reference when turning.

Drum diameter

Use a drum micrometer to check drum diameter. Set the micrometer to the proper drum size. Then place the

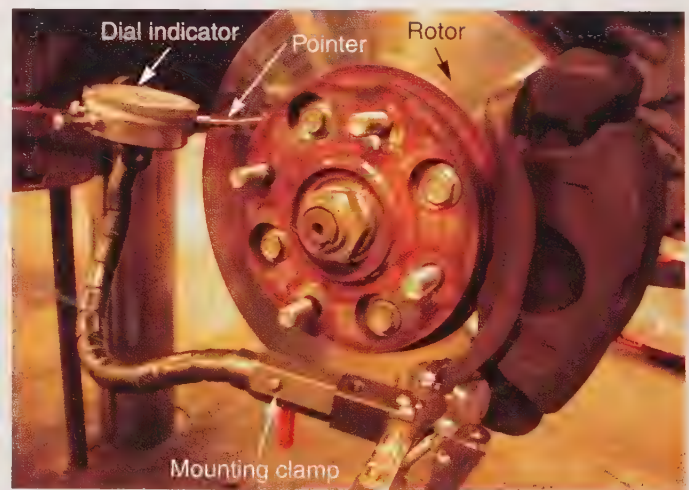


Figure 20-12. Use a dial indicator to check rotor runout. Always set the dial indicator according to the manufacturer's instructions. The base must be mounted on a stationary object, and the pointer must lightly contact the rotor surface.

micrometer in the drum so the micrometer pointers contact the braking surface, **Figure 20-13**. Slightly move the micrometer in the drum as shown until the maximum diameter is recorded. Check the drum size at several places around the drum. Ideally, the drum diameter should be checked every 45° (1/8 turn). Variations in drum diameter at different positions indicate the drum is out-of-round. This can be corrected by turning, as long as the drum minimum diameter is not exceeded. A drum that is already close to its maximum diameter will become unusable when it is turned to remove scoring. If the diameter of a drum is too large, or if turning it will make it too large, the drum should be replaced. Also check the drum for taper (outer diameter of the drum is greater than the inner diameter) by checking the diameter with the micrometer pointers at different depths.

Unbalanced drum or rotor

Although rare, an unbalanced drum or rotor can cause a vibration that is hard to track down. One of two methods can be used to track down an unbalanced drum or rotor.

One method can be used if the suspected unbalanced drum or rotor is on a drive axle. Remove both tires from the axle and reinstall the lug nuts to hold the rotor or drum in position. Then, place the vehicle in drive and slowly accelerate to the speed at which the vibration occurs. If the vibration is noted, remove one of the drums or rotors and recheck. If the vibration disappears, the unbalanced unit has been located. If the vibration is still present, reinstall the drum or rotor and remove the unit from the other side, then recheck.

An unbalanced drum or rotor can also be located with an off-car wheel balancer. Remove the drum or rotor from the vehicle and mount it on the wheel balancer. Set the controls as you would with a wheel and tire assembly, and then allow the machine to spin the rotor or drum. The needed amount of weight will be displayed on the control panel. As a general

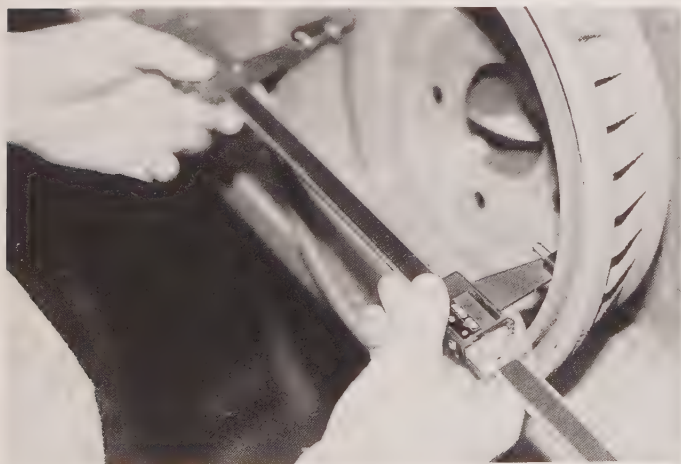


Figure 20-13. Drum micrometers are used to check variations in drum diameter. An out-of-round drum can cause serious vibration when the vehicle is braked. A badly warped drum will cause vibration at other times.

rule, if the machine calls for more than 3/4 ounce (21.3 grams), the rotor or drum should be replaced.

Engine Vibration Correction

The engine produces the power that the drive train delivers. This section covers NVH problems caused by engine cylinder problems. Other engine vibration problems, such as hesitation, surging, or detonation (pinging), are driveability related. All engine systems should be tested as part of a complete driveability diagnosis. Driveability diagnosis is primarily concerned with engine problems, and is a separate process from NVH diagnosis.

Engine missing

Engines deliver power with each power stroke. On modern engines, firing sequences are arranged so power impulses occur at precisely spaced intervals. One cylinder's power impulse occurs at every 1½ revolutions on a 3-cylinder engine, 2 revolutions on a 4-cylinder engine, 3 revolutions on a 6-cylinder engine, 4 revolutions on an 8-cylinder engine, and 5 revolutions on a 10-cylinder engine. Therefore, a miss on one cylinder will occur at an order of one-half of the number of cylinders. This means that orders of firing frequency caused by cylinder missing vary with the number of cylinders.

Running the engine with the transmission in Neutral or Park will often confirm an engine problem. Start the engine and increase rpm. An engine vibration will be felt as an increase that exactly matches the increase in rpm. Sometimes, placing a load on the engine will cause the vibration to be more noticeable. Internal engine problems causing a dead cylinder should be investigated by the following:

- ☐ Checking the ignition system to ensure all spark plugs are firing.
- ☐ Checking the fuel system to ensure that all injectors are opening properly.
- ☐ Checking the engine compression to isolate cylinder defects, such as burned valves or worn rings.



Note: A single cylinder miss is not caused by a fuel problem if the engine has a central fuel injection system or carburetor.

Preloaded engine mounts

A related and common engine problem is preloaded, or prestressed, engine mounts. Preloaded engine mounts have been installed in a manner that causes the rubber to be stretched or compressed. Stretched or compressed rubber cannot absorb vibration and simply passes the vibration to the body and on to the passenger compartment. To check for preloaded engine mounts, closely observe the rubber insert. If the rubber appears twisted or stretched, the mount may be preloaded.

To remove the tension from a preloaded engine mount, loosen, but do not remove, the bolts holding the

mount to the engine and frame. Start the engine and shift gears several times. This will reposition the mounts. Then, retighten the bolts.

Preloaded exhaust mounts

Preloaded exhaust system mounts have been stretched or compressed like a preloaded engine mount. Again, the mount cannot absorb vibration, and it transmits the vibration to the vehicle. To check for preloaded exhaust system mounts, allow the exhaust system to cool and then try to move the exhaust components. If the exhaust system does not have some play, the mounts are probably preloaded. To remove the tension, loosen the exhaust mount fasteners. Rock the exhaust system back-and-forth and from side-to-side. Allow the exhaust system to stop moving, and then tighten the fasteners without placing any forces on the exhaust components.

Belt or belt-driven accessory vibration correction

Many times a belt or belt-driven accessory will vibrate. These vibrations may be transferred from the engine to the passenger compartment and cause an NVH complaint. Common sources of objectionable vibration and noise are the belts and the air conditioner compressor. Alternators and power steering systems occasionally cause problems. Defective coolant and smog pumps usually create obvious noises that can be easily detected. To locate a belt or belt-driven accessory problem, simply remove the suspect belt and then start the engine. If the noise is gone, you have located the problem.



Caution: Do not operate the engine for more than a few seconds with the coolant pump disconnected. Lack of coolant circulation can cause localized engine overheating.

Belt vibration can usually be heard, as well as felt. Belt squealing is easy to recognize. Belts may also make chirping or knocking noises. Belts that are loose, glazed, or damaged are likely causes of these problems. Sometimes, especially with serpentine belts, belt material will stick in the pulley grooves. Most of these problems can be isolated by visual inspection.

Air conditioning compressors often vibrate. Whining, moaning, or rumbling noises may accompany this vibration. The easiest way to determine whether the problem is in the air conditioning compressor is to turn it off. If the compressor is the source of a vibration or noise, it will stop when the air conditioner is turned off. Common causes of compressor vibration and noise are loose fasteners or brackets or internal compressor damage. Sometimes, the drive belt must be removed to isolate a defective compressor clutch bearing.

Alternators may make whining or rattling noises. Loose housing bolts or an internal electrical problem may cause these noises. A slight whining noise from the alternator is normal. If the alternator whines, try unplugging the alternator field wire. If the whine stops, the alternator is defective. Most defective alternators are replaced.

Power steering systems may vibrate and become noisy due to a defective pump, restricted hoses, or clogged filter when used. A common cause of power steering noise is a low oil level. Many power steering problems become more obvious when the steering wheel is turned. The usual fix for power steering defects is to replace components.

Many cases of belt-driven accessory vibration can be corrected by installing extra brackets on the affected accessory.

If any part of the engine or an engine-driven accessory contacts the body or frame, vibration and noise will result. Usually, a visual inspection will locate parts that are contacting the body or frame.

Harshness Correction

Harshness is not usually confused with noise or vibration. Harshness complaints are not caused by unbalanced rotating components, but by uncontrolled contact between moving parts, or between the vehicle and the road. Common causes of harshness are discussed below.

Shock absorbers and springs

Many harshness complaints are caused by suspension problems. Many times someone has installed firm shock absorbers or MacPherson struts to improve handling. Although they may improve handling, they often make the ride much harder. Replacement springs may cause the same effect. Always begin a ride harshness complaint diagnosis by asking the owner if the shock absorbers or MacPherson struts have been changed recently. The only cure for stiff shocks, struts, or springs is to replace the parts.

Overinflated tires

Overinflated tires are often the cause of harshness. This should be the first thing checked when a ride harshness complaint is encountered. Air pressure on most modern automobile tires is around 32–35 psi (220–242 kPa). Truck and SUV tires may require higher pressures, usually in the 40–50 psi (276–345 kPa) range.

Loose drive shaft and CV axle parts

Loose drive shaft and CV axle parts cause clunking or thumping noises when the vehicle is put into gear or when accelerating or braking. Loose drive shaft and CV axle parts may also cause vibration. Checking for loose drive shaft and CV axle parts was covered in Chapter 13 and Chapter 15.

Part contact with vehicle body

Loose or bent parts may contact the vehicle body or frame and produce noises. This type of noise will usually be loud and intermittent (no set pattern). Suspension and exhaust system parts are the most likely to strike the body. When this is suspected, always make a close inspection for contact points. Sometimes the contact area will be shiny where the parts have been rubbing. Reposition or replace parts where necessary.

Isolating NVH Signals

When the NVH problem cannot be eliminated at the source, it can sometimes be corrected by **insulating** or **isolating** the source. A rubber bushing or a gap between parts can isolate the part, eliminating the problem. This is why maintenance of existing rubber suspension bushings and proper positioning of steering and suspension parts is so important.

Sometimes engine and power train-related parts such as accelerator or parking brake cables, air conditioning and power steering hoses, or wiring harnesses can contact the body or frame in ways that cause noises to be produced.

Extra insulation can be installed. In some cases, the existing insulators can be replaced with new parts that have increased NVH absorption. If a part is contacting the body or frame, it may be possible to reposition it so that the contact is eliminated.

Summary

NVH is the abbreviation for noise, vibration, and harshness. To diagnose NVH complaints, the technician must understand the definition of vibration and harshness, types of vibration and harshness, and how they are transferred to the passenger compartment. The technician must also understand the relation of vibration and harshness to noise.

Vibration is a repetitive motion of a rotating part and can be axial or radial. Axial vibration is a back-and-forth movement of a shaft along its rotational axis. Radial vibration is a side-to-side movement of a rotating part along its rotational axis. Radial vibration is the most common cause of vibration in an automotive drive shaft. How often vibrations occur is measured in terms of frequency. The strength of vibration is called its amplitude. The number of times a vibration occurs during one revolution of a rotating part is called vibration order.

Vehicle manufacturers reduce NVH by balancing and fitting moving parts, installing weights on drive train parts, and insulating the body and passenger compartment from moving parts. Wear and damage, however, can cause the vehicle to develop an NVH problem. Occasionally a part on a new vehicle, or a replacement part, may be defective and cause an NVH complaint.

Most vibration is caused by rotating parts that are loose, bent, or out-of-balance. A vibration does not become a problem unless the driver and passengers feel it. The only way a vibration can reach the driver and passengers is through a transfer path. Noise is always the result of vibration. Vibration in a dashboard part may cause a noise. Harshness is the action of a vehicle component in a way that is harder or more severe than normal. Loose parts or a lack of flexibility in a damping part are the usual cause of drive train harshness.

To diagnose NVH problems, some special tools will be needed. These include micrometers, dial indicators, scan tools, wheel balancers, vibration testers, and brake micrometers.

The seven-step troubleshooting process works to troubleshoot any NVH problem. Always verify the complaint, check for obvious causes, determine which component or system is the most probable cause of the problem, perform pinpoint tests, recheck possible causes, correct the defect, and recheck system operation.

To correct an NVH complaint, the technician must eliminate or damp the NVH source. There are many methods of eliminating sources of NVH. These include balancing rotating parts, replacing bent or loose parts, and aligning rotating parts. The usual method of correcting NVH complaints in the driveline is shaft alignment.

Tire and wheel problems can be corrected by checking tire balance and rebalancing when necessary, checking air pressure and tire condition and replacing defective tires, and checking wheel rim runout. Brake system vibration can be isolated by measuring drums to determine whether they are out-of-round and checking the rotor for excessive runout. Out-of-round drums and rotors with excessive runout can be corrected by turning or by replacing the drum or rotor. Occasionally an unbalanced drum or rotor can cause vibration. Drum and rotor balance can be checked with a tire balancer.

The engine may be the source of an NVH problem. Many engine NVH problems are caused by a dead cylinder, while others are driveability related. Preloaded engine or exhaust mounts may also cause engine-related NVH problems. The drive belts, air conditioner compressor, alternator, and power steering system may cause NVH problems. Many harshness complaints are caused by suspension problems, overinflated tires, a loose drive shaft or CV axle, or moving parts contacting the body or frame. Many of these complaints can be corrected by replacing defective parts, removing preloads from mounts, and, if no other correction is possible, damping the transfer path or isolating the source of vibration.

Review Questions—Chapter 20

Answer the following questions using the information provided in this chapter.

1. An NVH complaint may take the form of the driver complaining of _____ in the steering wheel or seats. Drivers may also complain about sounds from the _____ or dashboard.
2. NVH is the abbreviation for _____, _____, and _____.
3. A back-and-forth vibration is called _____ vibration. A side-to-side vibration is called a _____ vibration.
4. What are some causes of second order vibrations?
5. What three methods do vehicle manufacturers use to reduce NVH?
6. A reed tachometer works best when locating vibrations of _____ – _____ Hertz.

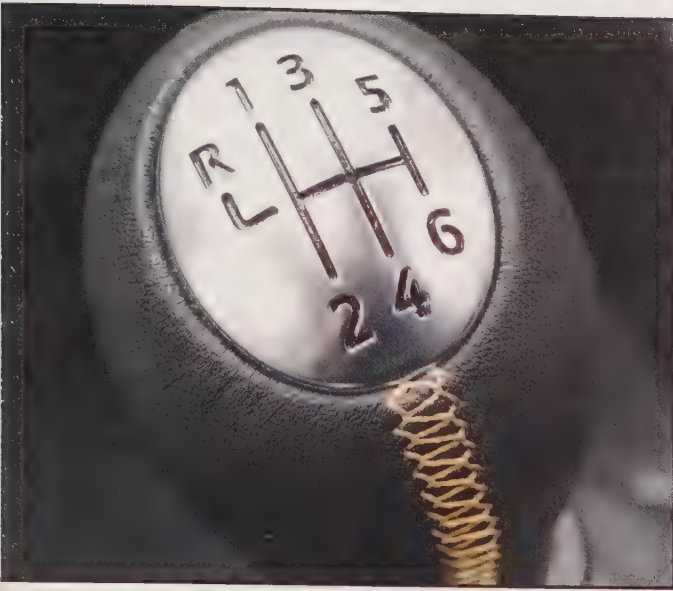
7. A wheel balancer can be used to balance tires and also to check the balance of ____.
8. To check brake drums and rotors for proper thickness and out-of-round conditions, a special type of ____ is needed.
9. What should the technician do in step two of the seven-step troubleshooting process?
10. What should the technician do in step six of the seven-step troubleshooting process?
11. Thoroughly checking the vehicle to locate any hidden problems that may cause the original problem to reoccur is called ____.
12. Drive shaft vibration occurs at a(n) ____ frequency than wheel vibration.
13. In your own words, define wheel rim runout.
14. The first step in removing the tension from a preload-engine mount is to ____ the bolts holding the mount to the engine and frame.
15. Drive belts may make ____, ____, or ____ noises.
16. A slight ____ noise from an operating alternator is normal.
17. Some belt-driven accessories can only be corrected by installing extra ____.
18. Under what three conditions is a loose driveline part most likely to make a noise?
19. When loose or bent parts contact the body, the noise they make will be intermittent. What does intermittent mean?
4. Electronic vibration testers have each of the following *except*:
 - (A) programming cartridge.
 - (B) separate vibration sensor.
 - (C) frequency sensitive reeds.
 - (D) 12-volt adapter.
5. A rotor micrometer is used to check _____.
 - (A) drum warping
 - (B) rotor thickness
 - (C) rotor runout
 - (D) drum balance
6. Technician A says that vibrations are the root cause of all noise complaints. Technician B says that vibrations are the root cause of all harshness complaints. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
7. Worn U-joints will cause vibration when the vehicle is ____ between 30 and 40 mph (48 and 64 km/h).
 - (A) accelerating
 - (B) cruising
 - (C) braking
 - (D) coasting
8. Each of the following tire defects is always easily observable *except*:
 - (A) sidewall damage.
 - (B) uneven tire wear.
 - (C) excessive tire wear.
 - (D) tire tread separation.

ASE-Type Questions—Chapter 20

1. Technician A says that most vibration complaints are caused by axial vibration. Technician B says that radial vibration is caused by parts that are out of balance. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
2. Each of the following statements about drive shaft vibration is true *except*:
 - (A) drive shaft vibrations occur whenever the vehicle is moving.
 - (B) vibration pulses occur at irregular intervals.
 - (C) frequency varies in direct proportion to shaft speed.
 - (D) the greater the amplitude, the stronger the vibration.
3. A common cause of harshness is a lack of ____ in a mounting part.
 - (A) flexibility
 - (B) balance
 - (C) pressure
 - (D) lubrication
5. A miss on one engine cylinder will occur at an order of ____ the number of cylinders.
 - (A) one-fourth
 - (B) one-half
 - (C) one-to-one
 - (D) twice
10. Technician A says that some insulators can be replaced with updated types that have greater vibration absorption ability. Technician B says that some moving parts can be tightly bolted to the frame to eliminate vibrations. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

Chapter 21

ASE Certification



After studying this chapter, you will be able to:

- ☐ Explain why technician certification is necessary.
- ☐ Explain the process of registering for ASE tests.
- ☐ Explain how to take the ASE tests.
- ☐ Identify typical ASE test questions.
- ☐ Identify the content of the ASE Engine Performance Test.
- ☐ Explain what is done with ASE test results.

Technical Terms

National Institute for Automotive Excellence (ASE)

Standardized tests

ASE-certified technician

ASE-certified master technician

Admission ticket

Test score report

Recertification test

This chapter will explain the National Institute for Automotive Service Excellence (ASE) certification program, and the advantages of being ASE certified. This chapter also explains how to apply for and take the ASE tests.

ASE Tests

The concept of setting standards for skilled jobs goes back to ancient times. Metalworkers, weavers, potters, and other artisans often served long apprenticeships to learn the proper way of doing their jobs. Associations of skilled workers set standards and enforced rules of conduct. Ancient Egypt, Greece, and Rome had such associations, and many medieval industries were regulated by guilds. Many modern labor unions descended from early associations of skilled workers. Certification processes for aircraft and aerospace workers, and electronics technicians have existed since the beginnings of these industries.

This has not been true, however, of the automotive industry. Automobile manufacturing and repair began as a fragmented industry made up of many small vehicle manufacturers and thousands of small repair shops. Although the number of vehicle manufacturers decreased, the number of repair facilities continued to grow in number and in variety. Due to its fragmented, decentralized nature of the automotive repair industry, standards were difficult to establish. For years, there was no unified set of standards for automotive repair knowledge or experience. Anyone could claim to be an automotive technician, no matter how unqualified. This resulted in unneeded or improperly done repair work. As a result, a large segment of the public came to regard automotive technicians as unintelligent, dishonest, or both.

This situation began to change in 1972, when the **National Institute for Automotive Service Excellence**, now called **ASE**, was established to provide a certification process for automobile technicians. ASE is a nonprofit organization that encourages and promotes high standards of automotive service and repair. ASE does this by providing a series of tests on various subjects in the automotive repair, medium/heavy truck repair, school bus repair, collision repair/refinishing, engine machinist, and parts specialist areas. Specialized ASE tests in the areas of alternative fuels and advanced engine performance are also available. More than 40 automotive area tests are available.

For many years, the ASE tests were administered as written exams that required 6 to 8 weeks for grading. Now, all tests are taken on a computer and graded immediately. ASE has partnered with Prometric, a computer test service. Prometric provides computer-based testing for a variety of industries and government agencies.

The ASE tests are **standardized tests**, which means that the same test in a particular subject is given to everyone throughout the United States. Any person passing one or more of these tests and meeting certain work experience requirements is granted **ASE-certified technician** status in

the subject covered by that test. A technician who can pass all the required tests in the automotive, medium/heavy truck, engine machinist, or collision repair/refinishing areas and meets the experience requirements is certified as a **ASE-certified master technician** in that area.

The purpose of the ASE certification program is to identify and reward skilled and knowledgeable technicians. Periodic recertification serves as an incentive for updating skills and provides guidelines for keeping up with current technology. The test program allows potential employers and the driving public to identify good technicians and helps technicians advance their careers.

Many repair shops now hire only ASE-certified technicians. Many manufacturer-sponsored technician training and state emission inspector programs now require ASE certification for admission and course credit. Some states require ASE certification to perform certain system repairs. A common example is air conditioning system repair. Close to 400,000 technicians are now ASE certified in one or more areas.

The advantages the ASE certification program has brought to the automotive industry include increased respect and trust of automotive technicians, at least of those who are ASE certified. This has resulted in better pay and working conditions for technicians and an increased standing in the community. Thanks to ASE, automotive technicians are taking their place next to other skilled workers.

Other ASE Activities

In addition to the certification program, ASE is involved in several other activities, such as encouraging the development of effective training programs, conducting research on the best methods of performing instruction, and publicizing the advantages of technician certification. ASE is managed by a board made up of persons from the automotive and truck service industries, motor vehicle manufacturers, state and federal government agencies, and schools, as well as other educational groups and consumer associations. Other organizations affiliated with ASE include the National Automotive Technicians Foundation, Automotive Youth Educational Systems, the North American Council of Automotive Teachers, and the Automotive Training Managers Council.

The National Automotive Technicians Education Foundation, or NATEF, evaluates automotive training programs against standards developed by the automotive industry. Qualifying programs are awarded NATEF accreditation. NATEF has accredited certified automotive training programs in all fifty states at the high school and college levels. A NATEF program called Continuing Automotive Service Education, or CASE, evaluates training centers that are geared to helping the working technician keep up with changes in automotive technology.

Automotive Youth Educational Systems (AYES) is a partnership among automotive manufacturers, dealerships, and ASE-certified secondary automotive programs. The

mission of AYES is to expose young people to the possibility of careers in automotive service. It also prepares students for entry-level automotive service jobs with its dealership partners or for advanced automotive technology studies.

The North American Council of Automotive Teachers, known as NACAT, is an international organization serving professional automotive technology teachers and trainers. NACAT's mission is to develop and maintain a strong professional organization to promote, update, and improve automotive service education.

Original equipment and aftermarket automotive training professionals founded the Automotive Training Managers Council, or ATMC. ATMC's purpose is to use networking and the exchange of ideas to improve training performance and help its members stay current with the latest products and techniques. ATMC also performs research and publishes information related to automotive training and technology issues.

ASE Test Windows

One reason that ASE went to computer-based tests was to allow more flexible testing times. Tests are offered during four test periods each year. The test periods are called windows. Each window is approximately two months long.

The exact date of the windows will vary slightly from year to year. Refer to the ASE website for upcoming test windows. Tests can be taken during the day or at night. In some areas, tests can be taken on weekends. The technician can reserve a specific day and time when registering.

Applying for the ASE Tests

Anyone may apply for and take an ASE test. However, to become certified, the applicant must have two years experience working as an automobile or truck technician. In some cases, training programs or courses, an apprenticeship program, or time spent performing similar work can be substituted for all or part of the work experience.

Special accommodations will be provided for those needing them under the Americans with Disabilities Act (ADA). See the ASE website for more information and to request forms for special accommodations.

To apply for an ASE test, access the ASE website. Typing 'myase' into any web browser will allow you to access this site.



Note: If you do not have access to the Internet, call Prometric at 1-877-346-9327 to schedule tests.

Once on the website, follow instructions to create a personal myASE account page. Once your personal page is

created, you will be directed to a registration page. Click on the page to see the available tests. Then select the test(s) that you want to take by clicking the mouse pointer on the appropriate buttons.

Once you have selected the proper tests, click on the continue button to review your choices and select the closest Prometric test center. There are more than 750 Prometric test centers, located in every state. Most test centers are stand-alone facilities, while a few are located at university computer labs. Determine the closest test center and record its number in the appropriate space. You will then be directed to another screen to pay for the tests. Once the payment is made, you will be able to print out a test **admission ticket**. See **Figure 21-1**.



Note: The ASE website also contains a computer test demonstration exam. If you are unused to computer operation, you should take this demonstration exam.

Taking the ASE Tests

Be sure to bring your admission ticket with you when reporting to the test center. Prometric advises that you arrive about 30 minutes ahead of your scheduled appointment time to ensure that you have time to check in. When you arrive at the test center, you will be asked for the admission ticket and a driver's license or other signed photographic identification. This is all you need to take the tests. Keep in mind that Prometric administers tests in many areas and that some of your fellow test takers will have no connection to the automotive industry.

You will not be allowed to take any materials into the test area. Before you can take the tests you will be asked to empty your pockets of your keys, pens, wallet, cell phone, and all other contents and store them in a keyed locker that is provided.

You will be given scratch paper and pencils before entering the test center. If you are taking an advanced level test, you will also be given a composite vehicle booklet. After you enter the test center and are seated by the test administrators, use the computer mouse to select choices as they are presented on the computer screen. You will not have to re-enter your personal information, as it is already on file from the registration process. During the actual test, carefully read each test question before deciding on the proper answer. Use the mouse to place the cursor over the button for the proper answer and click once. To change your answer, place the cursor over the appropriate button and click once. Once you have made your choice, click on the "next question" button.

The test is set up to give you a chance to go back and check your answers, and you can flag ones that you are not sure of. This way, you can review your answers again



National Institute for
AUTOMOTIVE SERVICE EXCELLENCE

ASE Test Registration Ticket

2012 Spring

Johanson, Chris
Greenville, South Carolina
ASE ID: ASE-2430-0891

Updated: March 27, 2012
10:13:53 AM

Unscheduled Tests

You do not currently have any unscheduled tests.

Making a Testing Appointment

You must schedule an appointment for any tests listed above and complete all testing by the deadlines shown, or you will forfeit your fees. To make an appointment, go online to myASE (www.ase.com/myase) or call Prometric at 1-877-346-9327.

Confirmed Appointment Summary

Date & Time	Tests	Test Center
May 09, 2012 8:00 AM-12:45 PM	A3R - Manual Drive Train & Axles Recert A4R - Suspension & Steering Recert A6R - Electrical/Electronic Systems Recert A5R - Brakes Recert A1R - Engine Repair Recert A8R - Engine Performance Recert A7R - Heating & Air Conditioning Recert A2R - Automatic Transmission/Transaxle Recert	PROMETRIC TEST CENTER 10 ENTERPRISE BLVD SUITE #100 GREENVILLE, SC 29615

Driving Directions

East from Charlotte NC Take I-85S to I-385N, exit 51C. Take exit 39, Haywood Rd, and then turn right onto Haywood Rd. South from Atlanta take I-85N to I-385N, exit 51C. Take exit 39, Haywood Rd, and then turn right onto Haywood Rd turn right onto Orchard Park, then turn left onto Brendan Way.

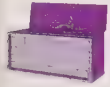
Arrive Early

Plan to arrive 30 minutes before the scheduled appointment to allow time for check-in. If you arrive late, you may not be allowed to test and will forfeit your fees.

Bring your Photo ID with Signature

Figure 21-1. ASE Test Registration Ticket. Bring this ticket along with signed photographic identification when you go to the test center. (ASE)

before submitting the test. Each test has a time limit, and you should work as quickly as possible while still giving proper attention to each question. Keep in mind that some questions, especially those having an electrical schematic, may take more time to answer. Other questions will be simpler and can be answered quickly. The test software will inform you when you have 15 minutes left to complete a particular test. The 15-minute warning applies to the test that you are taking at the time, not the total series of tests.



Note: All ASE tests are in English. An English-Spanish glossary of technical terms is, however, incorporated into the test program and can be accessed at any time during the test.

The ASE tests are designed to measure your knowledge of three things:

- ☐ Basic information on how automotive systems and components work.
- ☐ Diagnosis and testing of systems and components.
- ☐ Repairing automotive systems and components.

Types of ASE Test Questions

Each ASE test contains between 40 and 80 test questions, depending on the subject to be tested. All ASE test questions are multiple-choice with four possible answers. These types of multiple-choice questions are similar to the ASE-type questions used in this textbook. The following section discusses the types of ASE questions you are likely to encounter.

One-Part Questions

One-part questions require that you answer a single question:

1. Which of the following problems would *not* cause vibration on a rear-wheel drive vehicle at 55 mph (88 kph)?
 - (A) Bent drive shaft.
 - (B) Worn universal joints.
 - (C) Leaking slip yoke.
 - (D) Loose pinion-to-universal joint fasteners.

When answering any ASE question, always choose the best answer out of the four choices. In the above question, you are asked about the causes of drive shaft vibration. A bent drive shaft, worn universal joints, and loose pinion-to-universal joint fasteners could cause vibration. A leaking slip yoke, however, will cause a loss of lubricant but not vibration. Therefore the correct answer is (C) Leaking slip yoke.

Keep in mind that some ASE questions include irrelevant information. For example, what if the previous question were worded this way:

1. Which of the following problems would *not* cause vibration on a rear-wheel drive vehicle with a 3.08:1 rear axle ratio at 55 mph (88 km/h)?
 - (A) Bent drive shaft.
 - (B) Worn universal joints.
 - (C) Leaking slip yoke.
 - (D) Loose pinion-to-universal joint fasteners.

The fact that the vehicle has a 3.08:1 rear axle ratio is irrelevant. This information has no effect on the right answer, since the axle ratio would not have any effect on vibration. However, if you don't realize that the axle ratio information has no bearing on the question, you could get sidetracked looking for hidden meanings. You might end up choosing another answer or simply wasting time that could be spent on other questions.

Two-Part Questions

Two-part questions require you to analyze statements made by two technicians, Technician A and Technician B. Both statements can be true, both can be false, or one can be true and the other false. Basically, you must determine whether each of the statements is true:

1. Technician A says that CV joints require chassis grease for lubrication. Technician B says that a torn CV boot will cause the CV joint to lose all lubricant in a short time. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.

You know from earlier chapters that Technician A's statement is false. CV joints use special lubricant, not chassis grease. Since (A) is not a correct answer, you can also eliminate (C) because both technicians cannot be right if Technician A is wrong. Since a torn CV boot will cause the CV joint to lose all lubricant in a short time, Technician B is right and the correct answer is (B).

Remember, if you can determine whether Technician A or Technician B is correct, you can save time by eliminating (C) or (D). For example, if either Technician A or Technician B has made a correct statement, (D) cannot be the answer. If either Technician A or Technician B has made an incorrect statement, (C) cannot be the answer.

A variation of the two-part question describes a vehicle problem or a subject under discussion. Technicians A and B again make statements, and you must determine whether both statements are true, both statements are false, or one statement is true and one, false.

1. The clutch pedal of a vehicle with a 6-speed transmission requires excessive foot pressure to depress. The clutch has a hydraulic clutch release using brake

fluid. Technician A says that the clutch hydraulic system may be contaminated with petroleum-based oil. Technician B says that a low fluid level is the most likely cause. Who is right?

- (A) A only.
- (B) B only.
- (C) Both A and B.
- (D) Neither A nor B.

To correctly answer this kind of question, you must read carefully to determine the exact nature of the problem. A low fluid level would keep the clutch from being released but would not cause a hard pedal. Therefore, Technician B has made an incorrect statement and answers (B) and (C) are incorrect. If the hydraulic system was contaminated with a petroleum-based oil such as motor oil or transmission fluid, the internal seals would swell. This would make the slave and master cylinder pistons and, consequently, the clutch pedal hard to move. Therefore, Technician A's statement is correct, making (B) the correct answer. Note that (D) cannot be the answer, because both Technician A and Technician B would have to be wrong.

Notice also that this question has an irrelevant piece of information. The fact that the transmission has six speeds has no bearing on the problem and should have been disregarded as you worked your way to the correct answer.

Negative Questions

Some questions are called negative questions. These questions ask you to identify the incorrect statement from four possible choices. They will usually have the word "except" in the question:

1. A five-speed transmission cannot be shifted into overdrive gear. All other gears can be used. This could be caused by each of the following defects *except*:
 - (A) bent or worn internal shift linkage.
 - (B) bent or worn external shift linkage.
 - (C) a disconnected overdrive solenoid.
 - (D) a disconnected overdrive shift fork.

The way to find the correct answer to this type of question is to find the answer that qualifies as an exception. The easiest way to do this is to first determine which three answers correctly answer the positive form of this statement. For example, a five-speed transmission that cannot be shifted into overdrive gear *can* be caused by (A), (B), and (D). Therefore, (C) would be the correct answer, since it is the exception.

Another thing to remember while taking the test is that the ASE tests are geared to knowledge that applies to current vehicles. If, for instance, you once worked on a 1960s car with an overdrive unit operated by an electric solenoid, you might be tempted to pick something besides (C) as the answer. Try to keep in mind, however, that ASE will not ask a question about a type of overdrive that has been out of production for over 30 years. ASE is interested in the answer that applies to modern vehicles.

When reading ASE questions that involve problem diagnosis, focus on vehicles that are no more than 10 to 12 years old.

A variation of the negative question will use the word *least*.

1. Shifting from third to fourth gear in a front-wheel drive transaxle requires very high effort. All other shifts require only normal effort. Which of the following defects is the *least* likely cause?
 - (A) Worn fourth gear synchronizer.
 - (B) Bent and binding 3-4 gear shift fork.
 - (C) Clutch not releasing fully.
 - (D) 3-4 shift collar teeth damaged.

All of the above problems could cause high 3-4 shift effort. You must eliminate the most common causes, leaving the one that is least common. A worn fourth gear synchronizer is a very likely cause, leaving (B), (C) and (D). Damage to the 3-4 gear shift fork or 3-4 shift collar could cause hard shifting. Therefore (B) and (D) are each likely causes, which leaves answer (C). If the clutch does not release fully, the 3-4 shift could be difficult. A clutch that does not fully release, however, almost always causes the other gear engagements to be hard. Therefore, the least likely cause of a hard 3-4 shift problem is (C).

The thing to keep in mind with this kind of question is that all the possible answers could cause the problem. You must decide which of them is least likely to be the cause. This relates back to what was said earlier: ASE test questions call for the best answer. This also pertains to ASE questions that use the word *most*. All of the answers may be correct to some extent. You must look for the answer that is the most correct.

Negative questions are designed to test your knowledge of all types of drive train parts. Imagine that you once had a manual transmission or transaxle with hard 3-4 shift that was caused by the clutch. It took you a week to figure it out, and it has stuck in your mind ever since. When you first see this question, you may be tempted to pick (A) or (B) instead of (C). But is the clutch the most likely cause of a hard 3-4 shift in most cases? With a little thought, you will realize that the very reason this problem stuck in your mind is because it was so unusual. It is truly the least likely cause.

Incomplete Sentence Questions

Some test questions are incomplete sentences. One of the four possible answers correctly completes the sentence:

1. An ohmmeter can be used to check _____.
 - (A) solenoid movement
 - (B) ECM output voltage
 - (C) speed sensor windings
 - (D) speed sensor permanent magnet

Once again, you must choose the best answer. Start by eliminating the obviously wrong answers. An ohmmeter cannot be used to check solenoid movement, because

movement is not an electrical property, so (A) is obviously wrong. To choose between (B), (C), and (D), consider what could be checked by an ohmmeter. ECM output voltage (B) is an electrical property, but it can only be checked with a voltmeter. The speed sensor permanent magnet (D) can only be checked with a waveform meter as the related shaft turns. The resistance of the speed sensor windings can be checked with an ohmmeter. Therefore, (C) is the correct answer.

Test Results

Computer-based tests are scored immediately and technicians will know before leaving the test center whether they passed or failed the tests. Test center personnel will print out an individual **test score report** for each test taken. The test center personnel will stamp and initial each print-out to guard against counterfeiting, **Figure 21-2**. The test score report will show the technicians' scores on the test(s), and whether this score is sufficient for certification. The test questions are also subdivided into general areas to help you to determine any weak areas that require more study. For example, the Auto Engine Performance test questions will be divided into such subsections as general diagnosis, lubrication and cooling systems, air induction and exhaust systems, fuel system diagnosis and repair, and cylinder head and drive train.

Proof of certification can be obtained at any time by going to the ASE website and accessing your personal myase account. A wall certificate and pocket certification card will be mailed to the technician at the end of the test period window. See **Figure 21-3**.

Technician Confidentiality

ASE takes the position that all ASE test results are confidential and provides them only to the person who took the test. This is done to protect your privacy. The only information that ASE will release is to confirm to an employer that you are certified in a particular skill area. Test results will not be provided to anyone else, including employers. This is true even if the employer has paid the test fees. If you wish your employer to know exactly how you performed on the tests, you must provide him or her with a copy of your test results.

If you fail a certification test, you can retake it again as many times as you would like. However, you must pay all of the applicable registration and test fees again. You should study all available information in the areas where you did poorly. A copy of the ASE Preparation Guide may be helpful to sharpen your skills in these areas. The ASE Preparation Guide is free and can be downloaded from the ASE website.

Recertification Tests

Once you have been certified in any area, you must take a **recertification test** every five years to maintain your certification. This helps ensure that you have kept up with current technology. Questions on the recertification test are slightly more difficult than those on the regular certification test, as they are designed to test the technician's knowledge of current technology. Most recertification tests will contain 20 to 25 questions.

The process of applying to take the recertification tests is similar to that for the original certification tests. Use the same website and pay the proper recertification test fees online.

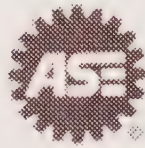
Summary

The automotive industry was one of the few major industries that did not have testing and certification programs. This resulted in decreased professionalism in the automobile industry, often leading to poor or unneeded repairs, and decreased status and pay for automobile Technicians. The National Institute for Automotive Service Excellence, or ASE, was started in 1972 to help overcome the poor status of the automotive repair industry. ASE tests and certifies automotive technicians in major areas of automotive repair. This has increased the skill level of technicians, resulting in better service, and increased benefits for technicians.

Each of the four ASE test windows is approximately two months long. Anyone can register to take the tests by filling out the online registration form and paying the proper registration and test fees. The registrant must also select the test center that he or she would like to go to. The technician can print out an admission ticket, which he or she must bring to the test center. To be considered for certification, the registrant must have two years of hands-on experience as an automotive technician.

The actual test questions will test your knowledge of general system operation, diagnosing problems, and repair techniques. All of the questions are multiple choice questions with four possible answers. The computer-based test procedure will provide test scores at the conclusion of the test session.

Results are confidential, and will be given only to the person who took the test. If a test was passed, and the experience requirement has been met, the technician will be certified for five years. Anyone who fails a test can take it again in the next session. Tests can be taken as many times as necessary. Recertification tests can be taken at the end of the five year certification period.



National Institute for
AUTOMOTIVE SERVICE EXCELLENCE
 DETAILED SCORE REPORT

Chris Johanson

ASE-2430-0891
 Test date: May 9, 2012

Your score is 22 (**Pass**)

The total score needed to pass A5R Automobile: Brakes Recert is 15 out of 23.

A5R Automobile: Brakes Recert

Content Area	Questions Answered Correctly	Total Number of Scored Questions
A. Hydraulic System Diagnosis and Repair	6	6
B. Drum Brake Diagnosis and Repair	2	2
C. Disc Brake Diagnosis and Repair	4	5
D. Power Assist Units Diagnosis and Repair	2	2
E. Miscellaneous Systems Diagnosis and Repair	4	4
F. Electronic Brake Control Systems Diagnosis and Repair	4	4
Total	22	23

Most ASE tests include some non-scored research questions that are not counted in your total score. Keep in mind that you pass or fail based on your total score.

Your test results are subject to verification by ASE, and will be checked to ensure accuracy. Please allow two business days for your online records to be updated with this test result.

ASE reserves the right to cancel any test score, bar participation in the ASE program, or revoke certification if there is any reason to suspect the validity of the score or any violation of ASE policies before, during, or after the test.

WORK EXPERIENCE REQUIREMENT

To become ASE certified, you must pass an ASE test and have at least two years of relevant hands-on working experience. You can download a Work Experience Report form at www.ase.com.

CREDENTIALS

Handwritten signature and date: 5/9/12

Figure 21-2. Upon completion of the test, the ASE Detailed Score Report is printed and made available.

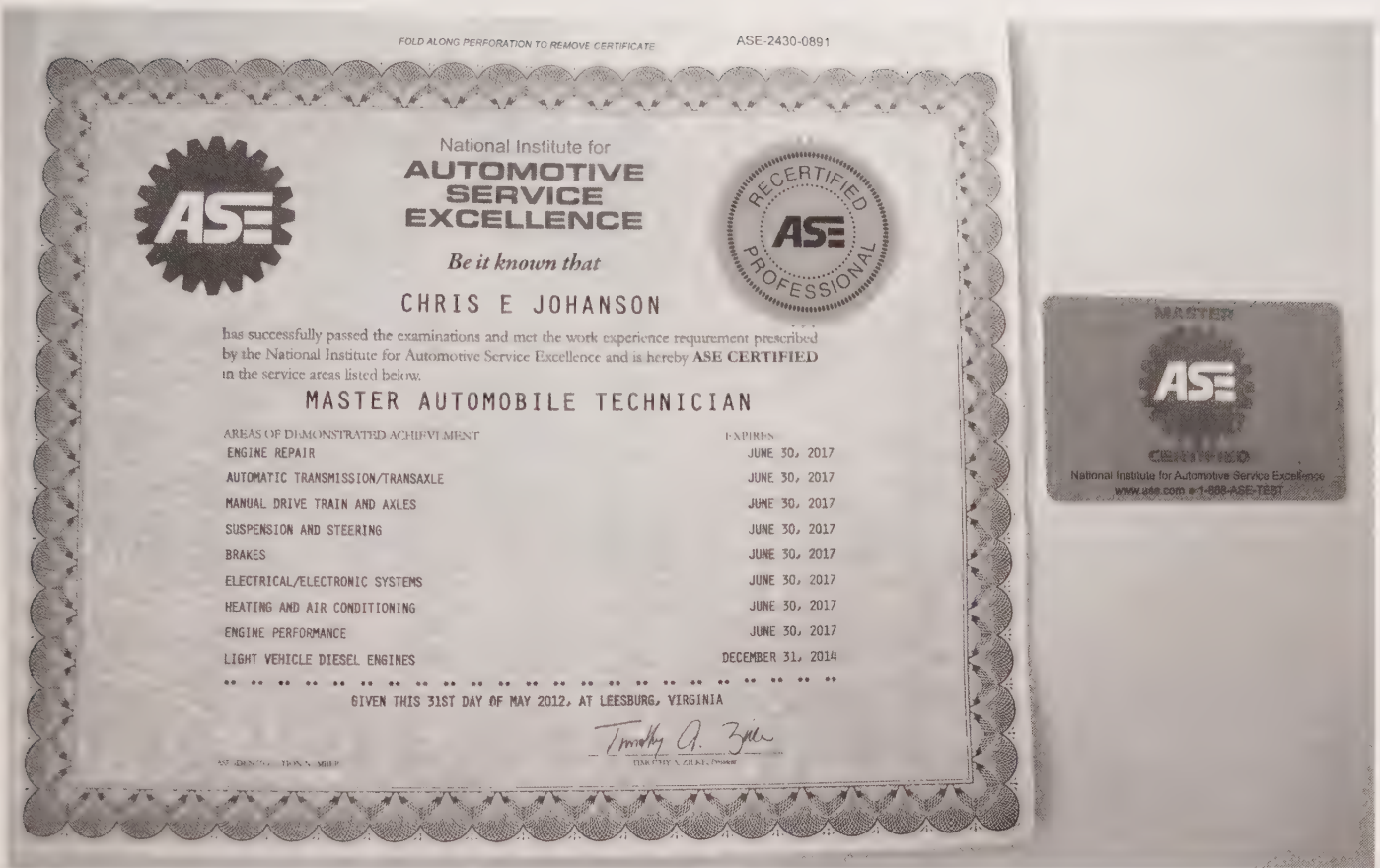


Figure 21-3. Certification materials include a wallet card and certificate that is suitable for framing.

Review Questions—Chapter 21

Answer the following questions using the information provided in this chapter.

- Associations of skilled workers who set standards and enforce rules of conduct have been established since _____.
 - ancient Egypt, Greece, and Rome
 - medieval times
 - 50 years ago
 - 1975
- ASE encourages high standards of automotive service and repair by providing a series of _____ tests.
 - written
 - hands-on
 - oral
 - computer-based
- When the same test in a particular subject is given to everyone throughout the United States, it is referred to as a _____ test.
 - comprehensive
 - fair
 - standardized
 - Both A and B.
- If a technician can pass all the required tests in the automotive, heavy truck, or collision/refinishing area, he or she is certified as a _____.
 - trainee
 - master technician
 - general technician
 - knowledgeable technician
- Which of the following will you *not* need to take the ASE tests?
 - At least two sharpened pencils.
 - Photographic identification.
 - Your admission ticket.
 - Both A and B.
- ASE tests are administered by a company called _____.
 - SAE
 - NIASE
 - Prometric
 - Standardized Test, Inc.
- The four computer based testing periods are called _____.
 - SAE
 - NIASE
 - Prometric
 - Standardized Test, Inc.

8. ASE provides test results to _____.
 - (A) the technician who took the test
 - (B) whoever paid for the test
 - (C) the technician's employer
 - (D) Both A and C.
 9. When will technicians taking computer-based ASE tests find out whether or not they passed the tests?
 - (A) After two weeks.
 - (B) After six to eight weeks.
 - (C) At the end of the two-month testing period.
 - (D) Before leaving the test center.
 10. If a technician's certification lapses, he or she must _____.
 - (A) take a recertification test
 - (B) take the regular test
 - (C) petition ASE
 - (D) None of the above.
5. When will the test taker be told whether or not he or she has passed an ASE test?
 - (A) As soon as they have finished taking the test.
 - (B) Within 24 hours of taking the test.
 - (C) In a confidential pass/fail letter within 7 business days.
 - (D) When certification verification arrives in 6 to 8 weeks.
 6. After you are finished with a test, you should _____.
 - (A) check to determine whether you have failed to answer any of the questions
 - (B) take a 15 minute break before going on to the next test
 - (C) help someone else with their test
 - (D) Both A and B.
 7. A technician can retake any certification test _____.
 - (A) two times
 - (B) four times
 - (C) five times
 - (D) any number of times

ASE-Type Questions—Chapter 21

1. The advantages that ASE certification has brought to automotive technicians include all of the following, *except*:
 - (A) increased respect.
 - (B) better working conditions.
 - (C) lower pay.
 - (D) increased standing in the community.
 2. ASE tests are given _____ each year.
 - (A) once
 - (B) twice
 - (C) four times
 - (D) twelve times
 3. ASE tests are designed to measure your knowledge of all of the following, *except*:
 - (A) basic information on how automotive systems and components work.
 - (B) knowledge of manufacturer specific technology.
 - (C) diagnosis and testing of systems and components.
 - (D) repairing automotive systems and components.
 4. ASE test questions resemble the ones in _____.
 - (A) college level courses
 - (B) essay-type tests
 - (C) verbal examinations
 - (D) this book
8. Technician A says that a detailed test score report is available to the technician on the computer screen. Technician B says that the test period window lasts all of a calendar year. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
 9. Technician A says that a technician can take a certification test any number of times. Technician B says that certification tests can be retaken at reduced fees.
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
 10. Certified technicians must take a recertification test every _____ years.
 - (A) 2
 - (B) 5
 - (C) 10
 - (D) There is no set time period.



Chapter 22

Career Preparation

After studying this chapter, you will be able to:

- ☐ Identify three classifications of automotive technicians.
- ☐ Identify the major sources of employment in the automotive industry.
- ☐ Identify advancement possibilities for automotive technicians.
- ☐ Explain how to fill out a job application.
- ☐ Explain how to conduct oneself during a job interview.

Technical Terms

Helper	Government-operated repair shop
Installer	Shop foreman
Certified technician	Service manager
New vehicle dealership	Salesperson
Department store service center	Service advisor
Independent auto repair shop	Parts specialist
General repair shop	Entrepreneur
Specialty shop	

Introduction

This chapter is an overview of career opportunities in the automotive service industry. It discusses types of automotive technicians and the kind of work they perform. This chapter also includes information on the types of repair outlets and the type of work, working conditions, and pay scales that the beginning technician can expect to find in each place. Also included are some of the ways you can locate jobs and become employed in the auto repair industry, as well as information on the types of automotive-related jobs you can move into. Studying this chapter will help you find and get a job in the automotive service industry.

Automotive Servicing

The business of servicing and repairing cars and trucks has provided employment for millions of people over the last 100 years. It will continue to provide good employment opportunities for many years to come. Like any career, automotive service and repair has its drawbacks, but it also has its rewards.

Most persons in the auto service business work long hours, and the diagnosis and repair procedures can be mentally taxing, physically hard, and often dirty. Automotive service has never been a prestigious career, but this is changing as vehicles become more complex and technicians become better trained. The technician often has to deal with difficult, condescending, and sometimes dishonest vehicle owners.

The advantages of the auto service business include the opportunity to work with your hands, less confinement than in many other professions, and the satisfaction of fixing something that is broken. Auto repair salaries are usually competitive with those for similar jobs, and it is a secure profession where the good technician can always find work. To ensure that you stay employable, always seek to learn new things, and become ASE certified in as many areas as possible.

Levels of Automotive Service Positions

Although the public tends to classify all automotive technicians as "mechanics," there are many types of auto service professionals. The types of auto service professionals range from the helper, who changes oil or performs other simple tasks; through the installer, who removes and installs parts; to the certified technician, who is capable of diagnosing and repairing various automotive systems. Although these levels are unofficial, they tend to hold true throughout the automotive repair industry. It would be possible to further break these levels down into more

sublevels, but these three adequately cover the general skill classifications. These levels are explained in more detail in the following sections.

Helpers

The **helper** performs basic service and maintenance procedures, such as installing and balancing tires, changing engine oil and filters, and cleaning parts, **Figure 22-1**. The skills required of the helper are low, and the pay will be less than that of the other levels. However, the helper position is a good way for many people to get started in the automotive repair field. In fact, many technicians started out doing this kind of automotive service when they were in their teens.

Installers

The **installer** is an automotive service person who installs parts on vehicles, **Figure 22-2**. They may remove and replace drive train components, and install shock absorbers or struts, mufflers and other exhaust system components; and possibly brake master cylinders, alternators, and starters. Installers seldom do complicated repair work, and they do not generally diagnose vehicle problems. Installers are paid more than helpers but less than certified technicians. Many installers take the opportunity to improve their knowledge and skills, and then eventually become certified technicians.

Certified Technicians

Certified technicians are at the top level and have the skills to prove it, **Figure 22-3**. Most technicians are ASE certified in at least one automotive area, and many are certified in all car or truck areas. The certified technician is able to successfully diagnose and repair every area that he



Figure 22-1. Helpers generally do basic work. This helper is cleaning the outside of a transmission case in preparation for disassembly.



Figure 22-2. This installer is preparing to reinstall a transaxle.

or she is certified in and can perform many other service jobs. The certified technician is at the top of the pay scale.

Types of Auto Service Facilities

There are many types of auto service facilities where the technician can work. The traditional place to get started in automotive repair—the corner service station—is gone, having been replaced by self-serve stations. However, many opportunities to repair vehicles still exist. Even the smallest community has many types of automotive repair facilities. Some of these are discussed below.

New Vehicle Dealerships

All **new vehicle dealerships** must have large, well-equipped service departments to meet the warranty service



Figure 22-3. This certified technician is rebuilding a manual transaxle.

requirements of the vehicle manufacturer. These service departments are usually equipped with special testers, tools, and service information needed to service the make of vehicle they sell. Dealership service departments are also equipped with lifts, parts cleaners, hydraulic presses, brake lathes, electronic test equipment, and other equipment for efficiently servicing vehicles. However, the technician must provide his or her own hand and air tools. Dealers stock all the most common parts and are usually tied into a factory parts network, which allows them to quickly obtain any part. See **Figure 22-4**.

Pay scales at most dealerships are based on flat-rate hours. The rate per hour is competitive between dealerships in the same area and usually higher than local industry in general. The number of hours the technician is paid for depends on the amount and type of work entering the shop and how fast he or she can complete it. If you can work fast and enough work comes in, the pay can be excellent. Most modern dealers offer some sort of benefits package.

Dealership working conditions are relatively good, and most of the vehicles serviced in a dealership are new or well-cared-for older models. Since the dealership service departments must fix any part of the vehicle, the technician can perform a large variety of work. Although many dealership service departments have technicians who work only in specific areas, the trend is toward training all technicians to handle any type of work. Most repairs will be on the same make of vehicle, although many large dealerships handle more than one make. Most modern dealerships are tied into manufacturer's hotlines. These hotlines are used to access factory diagnostic and repair information, which makes it easier to troubleshoot and correct problems.



Figure 22-4. New car dealerships offer excellent working conditions and benefits. However, you have to deal with all types of vehicle problems. There is not a very good opportunity for specialization. (Land Rover)

The disadvantages of dealership employment are the lack of salary guarantees, low pay rates for warranty repairs, and fast-paced, often hectic, working conditions. If you welcome the challenge of being paid by the job and do not mind working under deadlines, a dealership may be the ideal employer. Also, check out the local large truck dealerships. Although the work is much heavier, the pay is usually somewhat higher and working conditions are not as fast paced.

Chain and Department Store Auto Service Centers

Many national chain and department stores have auto service centers where various types of automotive repairs are performed. See **Figure 22-5**. These **department store service centers** often hire technicians for entry-level jobs and may have several classifications above entry-level. Technicians in most of these situations are paid a salary plus a commission for work performed. Pay scales for the various classifications of work are competitive, and most companies offer generous benefit packages. One advantage of working for large companies is the chance of advancement into other areas, such as sales or management.

One disadvantage of working at the average auto center is the lack of variety. Most auto centers concentrate on a few types of repairs, such as brake work and alignment, and turn down most other repairs. The work can become monotonous due to the lack of variety. Although the job pressures are usually less than those at dealerships, customers still expect their vehicles to be repaired in a reasonable period of time. However, if you would enjoy the opportunity to work on only one or two areas of automotive repair, this type of job may be ideal for you.

Specialty Shops

Tire, muffler, and other specialty shops can offer good working conditions and good pay. Most specialty shops concentrate on one area of service and are fully equipped to handle all aspects of their particular specialty. These shops may occasionally take on other types of repair work

when business in their specialty is slow. Examples of these types of shops are Midas and Miencke muffler shops, AAMCO transmission shops, and the auto centers of various tire manufacturers. These shops usually offer a base salary plus commission for work performed. Pay scales are generally competitive. A disadvantage of specialty shops is the lack of variety. Since they concentrate on a few types of repairs, working at these shops can become monotonous.

Many specialty shops are franchise operations, and the demands of the franchise can create problems. If the prime purpose of the shop is to sell tires, for instance, the technician who was hired to do steering and suspension repairs may be forced to spend time installing tires. This can be annoying to most technicians who want to be doing the job they were hired for. However, if this does not bother you, the specialty shop could be a good work situation.

Independent Shops

There are millions of **independent auto repair shops**, such as the one shown in **Figure 22-6**. As places to work, they range from excellent to terrible. Many shops are run by competent and fair-minded managers and have first-rate equipment and good working conditions. Other independent shops have almost no equipment, low pay rates, and extremely poor, even dangerous, working conditions. The prospective employee should carefully check all aspects of the shop environment before agreeing to work there. Technicians at independent shops are usually paid on a salary plus commission basis.

There are two major classifications of independent repair shops, the general repair shop and the specialty shop. The **general repair shop** takes in most types of work and offers a variety of jobs. General repair shops may avoid some repair jobs that require special equipment, such as automatic transmissions, alignment, or air conditioning service. However, they will usually take a variety of other repair work on different makes and types of vehicles. This can be a good place to work if you like to be involved in many different types of diagnosis and repair.

Specialty shops confine their repair work to one area of repair, such as transmissions, tune-up, brake repair, or alignments. They are fully equipped to handle all aspects of their particular specialty. These shops can be ideal places to work if you want to concentrate on one area of repair.



Figure 22-5. Chain store automotive service centers employ many technicians.

Government-Operated Shops

Many local, state, and federal government agencies maintain their own vehicles. **Government-operated repair shops** can be good places to work. Employees are generally paid on an hourly or weekly basis. Pay is usually set by law, with no commission. Although civil service pay scales are lower than private industry, the benefits are usually excellent. Pay raises, while relatively small, are regular. Technicians in most government shops work a 35- or 40-hour week and have the same holidays as other government employees.



Figure 22-6. This independent repair shop will perform a variety of repairs on all types of vehicles. Some independent repair shops, however, confine their repairs to one general area, such as brakes or transmissions.

The working conditions in most government shops are good, without the stress of deadlines or having to deal with customers. Hiring procedures are more involved than they are with other auto repair shops. Prospective employees must take civil service examinations, which often have little to do with automotive subjects. Some government agencies require a certain level of education, thorough background checks, lists of former employers or other references, and may require that the employee be a registered voter.

If you think that you would be interested in working for a government-operated repair shop, contact your state employment agency for the addresses of local, state, and federal employment offices in your area.

Other Opportunities in the Auto Service Industry

Many other opportunities are available to the automotive technician. These jobs still involve the servicing of vehicles, without some of the physical work. If you like cars and trucks but are unsure whether you want to make a career of repairing them, one of these jobs may be for you.

Shop Foreman or Service Manager

The most likely automotive promotion that you will be offered is **shop foreman** or **service manager**. Many repair facilities are large enough to require one or more foremen or service managers. If you move into management from the shop floor, your salary will increase and you will be in a cleaner, less physically demanding position. Many technicians enjoy the management position because it lets them in on the fun part of service—troubleshooting—without the drudgery of actually making the repairs.

The disadvantage of a move to management is that you will no longer be dealing with the logical principles of

troubleshooting and repair. Instead, you will deal with the illogical and arbitrary personalities of people. Both the customers and technicians will have problems and attitudes that you will have to deal with. Unlike a vehicle problem, these problems require considerable personality and tact. Sometimes the manager has to compromise, which can be hard for the person who is used to being right.

The paperwork load is large for any manager and may not be something that a former technician can get used to. Record keeping requires a good bit of desk, and usually, computer time. Automotive record keeping is like balancing a checkbook and writing a term paper every few days. If you do not care to deal with people or keep records, a career in management may not be for you.

Salesperson or Service Advisor

Many people enjoy the challenge of selling. The **salesperson** or **service advisor** performs a vital service, since repairs will not be performed unless the owner is sold on the necessity of having them done. Salespersons are not necessary in many small independent shops, but are often an important part of dealership service departments, department store service centers, and specialty repair shops.

The salesperson may enjoy a large income and be directly responsible for a large amount of business in the shop. However, selling is a people-oriented job, and takes a lot of persuasive ability and diplomacy. If you are not interested in dealing with the public, you will probably not be happy in a sales job.

Parts Specialist

One often overlooked area of the automotive service business is the process of supplying parts. It is as vital as any other area. There are many types of parts outlets, including dealership parts departments, independent parts stores, parts departments in retail stores, and combination parts and service outlets. All of these parts outlets meet the needs of technicians and shops, as well as the do-it-yourself needs of the vehicle owner. The many different makes of vehicles, as well as the complexity of every modern vehicle, means that a large number of parts must be kept in stock and located quickly when needed.

Parts specialists are trained in the methods of keeping the supply of parts flowing through the system until they reach the ultimate endpoint, the vehicle. Parts must be carefully checked into the parts department and stored so that they can be found again. When a specific part is needed, it must be located and brought to the person requesting it. If more of the same parts are needed, they must be ordered. If the part is not in stock, it must be special ordered. This can be a challenging job.

The job of the parts specialist appeals to many people. This job does not pay as much as some other areas of automotive service, but rates are comparable with other jobs with the same skill level. If this type of work appeals to you, it may be a good job choice. There is an ASE test for

parts specialists, and you may want to consider taking it to enhance your employability.

Self-Employment

Many persons dream of going into business for themselves. This can be a good and profitable option for the good technician. However, in addition to mechanical and diagnostic ability, the person with his or her own business must have a certain type of personality to be successful. This type of person must be able to shoulder responsibilities, handle problems, and look for practical ways to increase business and make a profit. This type of person must maintain a clear idea of what plans, both long and short term, need to be made. A person like this is often called an **entrepreneur**, in other words, a person who has the energy and skill to build something out of nothing.

When you have your own business, all the responsibility for repairs, parts ordering, bookkeeping, debt collection, and a million other problems are yours. Starting your own shop requires a large investment in tools, equipment, and working space. If the money must be borrowed, you are responsible for paying it back. However, many people enjoy the feeling of independence, of not having to answer to an employer. If you have the personality to deal with the problems, you may enjoy being your own boss.

Another possible method of self-employment is to obtain a franchise from a national service chain. A franchise operation removes some of the headaches of being in business for yourself. Many muffler, tire, transmission, tune-up, and other nationally recognized businesses have local owners. They enjoy the advantages of the franchise affiliation, including national advertising, reliable and reasonable parts supplies, and employee benefit programs. Disadvantages include high franchise fees and startup costs, lack of local advertising, and some loss of control of shop operations to the national headquarters.

Getting a Job

There are many automotive jobs available at all times. The problem is connecting with the job when it is available. There are essentially two hurdles to getting a job—finding a job opening and successfully applying for the job. Below are some hints for overcoming these hurdles.

Finding Job Openings

Before applying for a job, you must know about a suitable opening. A good place to start is with your instructors. They often have contacts in the local automobile industry, and may be able to recommend you to a local company. Another good place to begin your search is the classified section of your local newspaper. Automotive jobs are often advertised in newspapers, especially those for automotive dealerships, specialty and franchise shops, and independent repair shops.

Also visit your local state employment agency or job service, **Figure 22-7**. Most of these agencies keep records of job openings, usually throughout the state, and may be able to connect to a data bank of nationwide job openings. Some private employment agencies specialize in automotive placement. If there is an agency of this type in your area, arrange for an interview with one of their recruiters.

Visit local repair shops that you are interested in working for. Sometimes these shops have an opening that they have not advertised. If you are interested in working for a chain or department store, most of these stores have a personnel department where you can fill out an application. Even if no jobs are available, your application will be placed on file in the event that a job becomes available in the future.

Applying for the Job

No matter how good your qualifications, you will not get a job if you make a poor first impression on the job interviewer. If you do not impress your potential employer as competent and dedicated, you will not get the job.

Start creating a good impression when you fill out the employment application. Type or neatly print when filling out the application. Complete all blanks, and completely explain any lapses in your education or previous employment history. List all your educational qualifications, including those that may not apply directly to the automotive industry. **Figure 22-8** shows a typical employment application.

When you are called for an interview, try to arrange for a morning interview, since your potential employer is most likely to be in a positive mood in the morning and less likely to be overwhelmed by last minute problems in the shop. Dress neatly, and arrive on time or a little early. When introduced to the interviewer, make an effort to repeat and remember their name. Speak clearly when answering the interviewer's questions. Do not smoke or chew gum during the interview. State your qualifications



Figure 22-7. State employment agencies have many job listings that are not normally advertised.

Employment Application

Date: _____ Social Security Number: _____

Name: _____ Age: _____ Sex: _____

Address: _____

Phone: _____ United States citizen? _____ Can you furnish proof? _____

Employment Desired

Position: _____ Date you can start: _____ Expected salary: _____

Are you currently employed? _____ May we inquire of your present employer? _____

Education

Circle the number for the highest level completed:

High School	Trade/Technical School	Community/Junior College	University
1 2 3 4	1 2	1 2	1 2 3 4

Other: _____

Specialized Training or Certifications: _____

Employment Record

Current/Last employer: _____ From: _____ To: _____

Address: _____ Phone: _____

Salary: _____ Job description: _____

Reason for leaving: _____

Previous employer: _____ From: _____ To: _____

Address: _____ Phone: _____

Salary: _____ Job description: _____

Reason for leaving: _____

Previous employer: _____ From: _____ To: _____

Address: _____ Phone: _____

Salary: _____ Job description: _____

Reason for leaving: _____

Figure 22-8. Typical employment application. Be sure to fill out the application completely.

for the job without bragging about or belittling your accomplishments. At the conclusion of the interview, thank the interviewer for his or her time. If you do not hear from the interviewer in a few days, it is permissible to make a brief and polite follow-up call.

Summary

The automotive service industry provides employment for many people and will continue to do so. Automotive service has some disadvantages, such as long hours, hard work, lack of status, and difficulties in dealing with the public. Advantages include interesting work, the security of a guaranteed career, and the enjoyment of diagnosing and correcting problems. Always stay employable by learning new things and taking the ASE tests.

The three general classes of technicians are the helper, the installer, and the certified technician. The helper does the simplest tasks, such as tire changing and lubrication. Many helpers move up into the other classes after a short time. The installer installs new parts, such as shock absorbers and strut assemblies, and sometimes moves into brake repair and wheel alignment. The certified technician performs the most complex diagnosis and repair jobs on vehicles and makes the most money.

There are many places to work as an automotive technician. Among the most popular are new car and truck dealers, auto centers affiliated with department or chain stores, specialty shops, independent repair shops, and government agencies. Some people prefer to have their own businesses, either as independent owners or as part of a franchise system.

Other opportunities in the automotive service field include moving into management as a foreman or service manager, or into sales as a service advisor or specialty salesperson. Another often overlooked employment possibility is in the automotive parts business.

To obtain a job in the automotive business, first locate possible job openings. Try the local newspaper and state employment agency. Also visit repair shops in your area. Most department or other large stores with attached auto service centers have personnel departments where you can fill out a job application. To get a job, you must make a good impression, no matter how qualified you are. Fill out all job applications carefully and neatly, listing your qualifications honestly. When invited to a job interview, dress neatly, arrive on time, and be courteous. Answer all questions without overstating or understating your abilities and experience. Follow up the interview with a brief phone call within a few days.

Review Questions—Chapter 22

Answer the following questions using the information provided in this chapter.

1. What are some disadvantages of working in the auto service business?
2. What are some advantages of working in the auto service business?
3. The _____ performs the easier types of service and maintenance.
4. The _____ is an automotive service person who installs parts on vehicles.
5. The _____ technician is able to successfully diagnose and repair every area that he or she is certified in.
6. All new vehicle dealerships must have well-equipped service departments to meet the _____ service requirements of the _____.
7. Pay scales at most dealerships are based on _____ hours.
8. Pay scales at government garages are based on a per hour or per week _____.
9. One advantage of a franchise operation is _____ advertising.
10. A good place to start looking for a job is at your state _____.

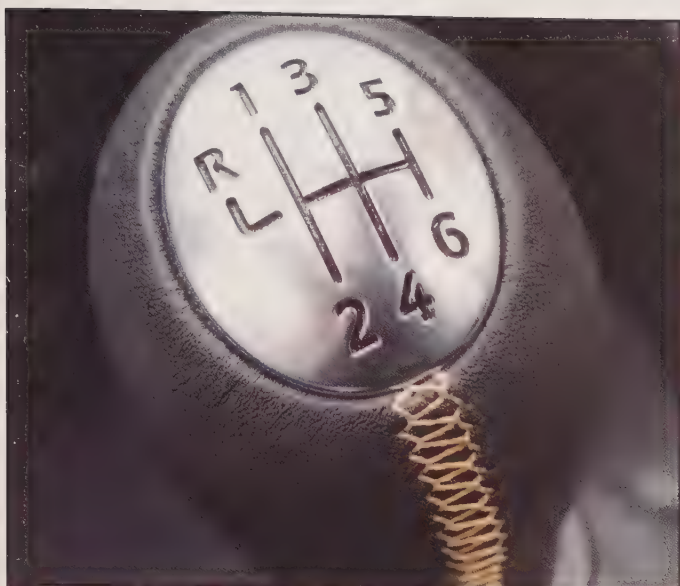
ASE-Type Questions—Chapter 22

1. Technician A says that one advantage of working in the automotive service field is the opportunity to work with your hands. Technician B says that one advantage of working in the automotive service field is the high prestige of the automotive technician. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
2. Each of the following automotive service jobs will *most* likely be done by a helper *except*:
 - (A) battery installation.
 - (B) tire changing.
 - (C) tire repair.
 - (D) suspension noise diagnosis.

3. In which of the following businesses can the automotive technician get a job doing only a few kinds of repairs?
 - (A) Chain stores.
 - (B) Corner service stations.
 - (C) Government garages.
 - (D) New vehicle dealers.
4. Each of the following statements about working for a specialty shop is true *except*:
 - (A) the variety of repairs is limited.
 - (B) the opportunity exists to become very skilled in one area of service.
 - (C) the technician may be paid by one of several methods.
 - (D) new vehicle warranty repairs are commonly performed.
5. One feature of working for a government-operated repair shop is the lack of _____.
 - (A) benefits
 - (B) security
 - (C) deadlines
 - (D) Both A and B.
6. At which of the following places is the automotive technician *most* likely to move up to a management position?
 - (A) The same shop where he or she is working.
 - (B) An automotive parts store.
 - (C) Another shop in the same area.
 - (D) A totally different business.
7. Each of the following is a job duty of the parts specialist *except*:
 - (A) obtaining parts for technicians.
 - (B) telling the technicians how to install parts.
 - (C) selling parts to the general public.
 - (D) special ordering parts.
8. Technician A says that job openings in the automotive service business are plentiful. Technician B says that automotive service shops often advertise in local newspapers. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
9. Technician A says that you should fill out the employment application in a sloppy manner to let the owner know that you are not a paper kind of person. Technician B says that filling out the employment application is a good time to start making a good impression. Who is right?
 - (A) A only.
 - (B) B only.
 - (C) Both A and B.
 - (D) Neither A nor B.
10. Each of the following helps to make a good impression during the job interview *except*:
 - (A) dressing in dirty work clothes.
 - (B) arriving a little early.
 - (C) not smoking.
 - (D) making an effort to remember the interviewer's name.



Automotive servicing can be a rewarding career to those with strong troubleshooting skills and to those who pursue ASE certification in as many areas as possible. (Ford)



Appendix A

Basic Electricity and Electronics

Basic Electrical Theory

The following appendix emphasizes electrical systems and components as they apply to drive train control systems. It illustrates how these components fit into the overall vehicle design and how they can affect vehicle drive train operation. The information presented here applies to any modern vehicle. For those who have not been exposed to basic electrical and electronic theory, this appendix begins with a brief review of these principles. Also included is a nontechnical discussion of computer components and control loop theory.

Atoms and Electricity

Everything is made of atoms. Every atom has a center of **protons** and **neutrons**. The neutrons have no charge, and the protons have a positive charge, making the center of the atom positively charged. Revolving around this center are negatively charged **electrons**. See **Figure A-1**. In the ideal atom, the number of electrons is exactly equal to the number of protons in the center. In actual practice, the number of electrons varies, and there is some movement of electrons between atoms. Electricity is the movement of large numbers of electrons from atom to atom.

Conductors and Insulators

Some atoms easily give up or receive electrons. Elements made of these atoms are good electrical conductors. **Conductors** allow the flow of electricity. Examples are

copper and aluminum. Materials whose atoms resist giving up or accepting atoms are insulators. **Insulators** resist the flow of electricity. Glass and plastic are good insulators. Some materials can alternate between conducting and insulating. These materials are called **semiconductors** and are discussed in the computer section later in this chapter.

Electron Flow

As mentioned before, electricity is the movement, or **flow**, of electrons. The path through which the electrons move is called a **circuit**. Electrons will not flow in a circuit unless two conditions are met:

- ❑ There are more electrons in one place than another. In a vehicle, the battery and alternator create this difference in the number of electrons.
- ❑ There is a connection between the two places. This connection is composed of the vehicle wiring and the electrical unit being operated. It must be made of materials that are good conductors.

A simple automotive electrical circuit is shown in **Figure A-2**. In this circuit, the electrical path is from the battery through the positive battery cable, fuse, brake light switch, brake lightbulbs, frame, and negative cable, and then back to the battery. This is called a **complete circuit**, since the electricity makes a loop through the battery, cables, fuse, switch, bulbs, frame, and back to the battery. The path for the electrons to return to the battery is as important as the path from the battery to the electrical device. When a circuit or component forms a complete path for electricity, it is said to have **continuity**.

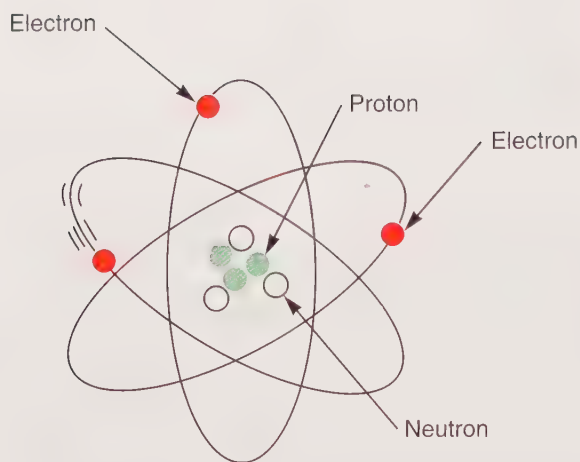


Figure A-1. Atom structure. The electrons travel around the nucleus, which is made up of protons and neutrons.

Electrical Properties

The flow of electricity through a circuit depends on three electrical properties, all of which can be measured. These electrical properties are explained below.

Current

Current is the number of electrons flowing past any point in the circuit. Current is measured in **amperes**, usually shortened to **amps**. The higher the amps rating, the more electrons are moving in the circuit.

Current is measured with an ammeter. To measure current in a circuit, the meter must be connected in series with the circuit. See **Figure A-3**. This allows the current to travel through the meter as it flows through the circuit.

Voltage

Voltage is electrical pressure, created by the difference in the number of electrons between two terminals. It

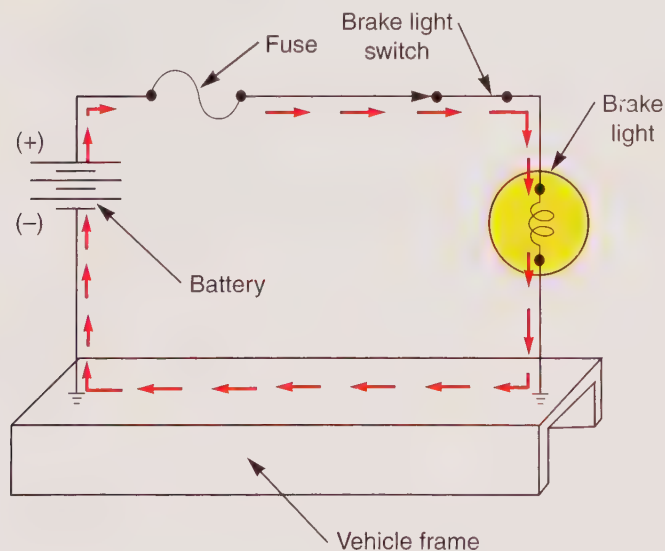


Figure A-2. A simple automotive electrical circuit.

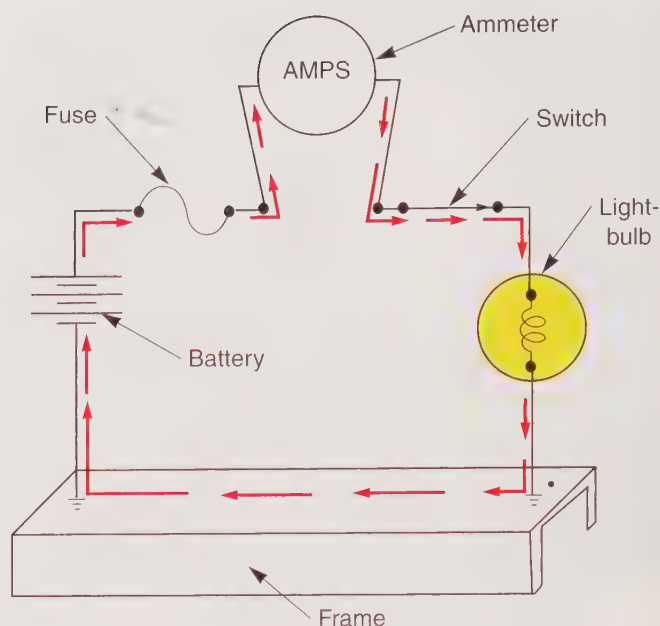


Figure A-3. An ammeter is connected in series to measure current in a circuit.

provides the push that makes electrons flow and is measured in **volts**.

Voltage is measured with a voltmeter. A voltmeter is connected in parallel with the circuit, **Figure A-4**.

Resistance

Resistance is the opposition of the atoms in a conductor to the flow of electrons. All conductors, even copper and aluminum, have resistance to giving up their electrons. Resistance is measured in **ohms**.

An ohmmeter is used to measure resistance. Power to the circuit must be disconnected before hooking up the meter. The ohmmeter is then connected to each end of the circuit or wire that is being checked. See **Figure A-5**.

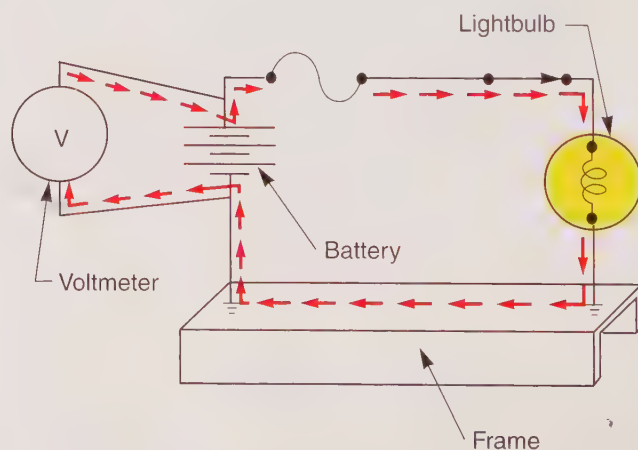


Figure A-4. When using a voltmeter, it must be connected in parallel with the circuit.

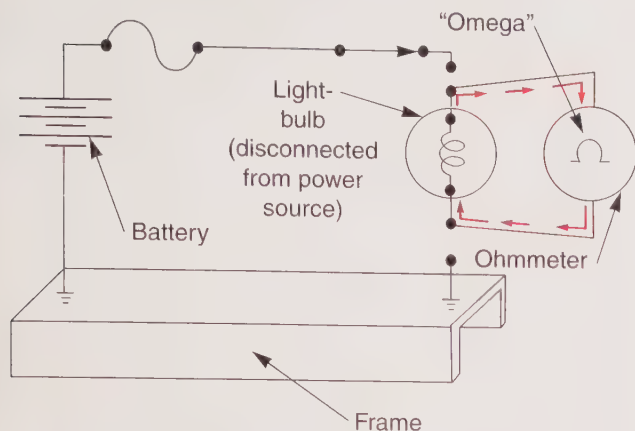


Figure A-5. To measure the resistance of a component, disconnect the power source before connecting the meter. If the ohmmeter is used in an energized circuit, the meter will be damaged. Make sure the power source is removed.

Ohm's law

Sometimes all the electrical properties in a circuit are not known. However, if you know two of the properties, you can calculate the third using **Ohm's law**. **Figure A-6** is a graphic representation of Ohm's law. It is sometimes called the Ohm's law triangle. In the triangle, the letter E represents volts, the letter I represents amps, and the letter R represents ohms.

To use the Ohm's law triangle, cover the unknown property and perform mathematical calculations using the other two. Using Ohm's law requires no more than simple multiplication or division.

$$\text{Amps} = \text{volts} \div \text{ohms}$$

$$\text{Ohms} = \text{volts} \div \text{amps}$$

$$\text{Volts} = \text{amps} \times \text{ohms}$$

When amperage is unknown, divide voltage by ohms to obtain the unknown amperage value. When resistance is unknown, divide voltage by amperage to obtain the unknown ohms value. When voltage is unknown, multiply amperage and resistance to obtain the unknown voltage value.

Direct and Alternating Current

The vehicle battery and alternator always have positive and negative terminals. There is always a shortage of



Figure A-6. A graphic representation of Ohm's law. To find an unknown value, cover the known value and perform the necessary mathematical calculations.

electrons at the positive terminal, and an excess of electrons at the negative terminal. Current flows in only one direction, from negative to positive. This is called a **direct current**, or **DC**, system.

In the systems used in homes, schools, and factories, the flow of electrons changes direction many times every second. These are **alternating current**, or **AC**, systems. A vehicle's alternator generates AC, but it is changed to DC to charge the battery. The engine, drive shaft, and wheel speed sensors used with drive train control systems also produce an AC current. This current is used to calculate speed of a rotating part.

Types of Electrical Circuits

There are three types of automotive circuits. Every wire in a car or truck is part of one of these types of circuits. The three types of circuits are series, parallel, and series-parallel.

The circuit in **Figure A-7** is the simplest type of automotive circuit, the **series circuit**. This series circuit consists of the vehicle battery, a switch, a lightbulb, and connecting wiring. Electrons flow through the wiring from the battery, through the switch and bulb, and back to the battery. The same current (number of electrons) flows through every part of the series circuit.

The circuit in **Figure A-8** is a **parallel circuit**. In a parallel circuit, current flow is split so that each part, or branch, of the circuit has its own current path. Different amounts of current will flow in different parts of the circuit, depending on the resistance of each part.

The **series-parallel** circuit has some components that are wired in series and some that are wired in parallel, as shown in **Figure A-9**. All current flows through some parts of the circuit, while the current path is split in other parts.

Circuit Defects

There are two types of wiring defects: shorts and opens. A **short circuit** is caused when the wire insulation fails or is removed and the wire contacts the frame, body, or another grounded part of the vehicle, **Figure A-10**. Not only is a needed part of the circuit bypassed, the current

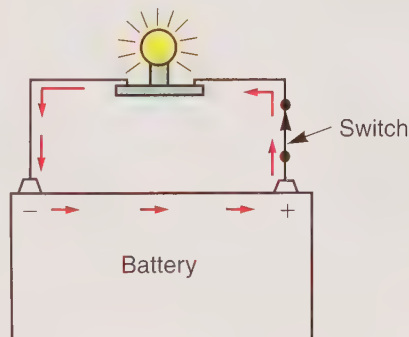


Figure A-7. A simple series electrical circuit.

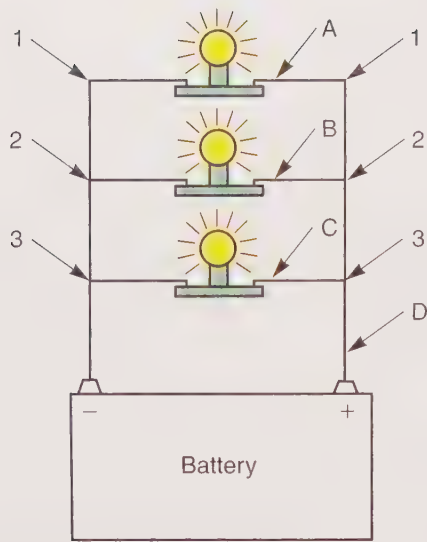


Figure A-8. A parallel circuit. Voltage across 1–1, 2–2, and 3–3 would be equal. Current flow in amperes at A, B, and C would depend on the resistance in its branch. Current flow at D would equal the sum of current flowing through A, B, and C. Total resistance of A, B, and C would be less than that in any single branch.

flow is too high. If a fuse or circuit breaker, discussed later in this chapter, does not protect the circuit, a short could lead to damaged wiring or components, or a fire.

An **open circuit** is a circuit that is not complete. Current cannot flow in an open circuit, as in **Figure A-11**. Common causes of open circuits are loose or corroded connections, disconnected wires, and defects in electrical components such as switches, bulbs, and fuses. A related problem is a high resistance electrical connection, usually

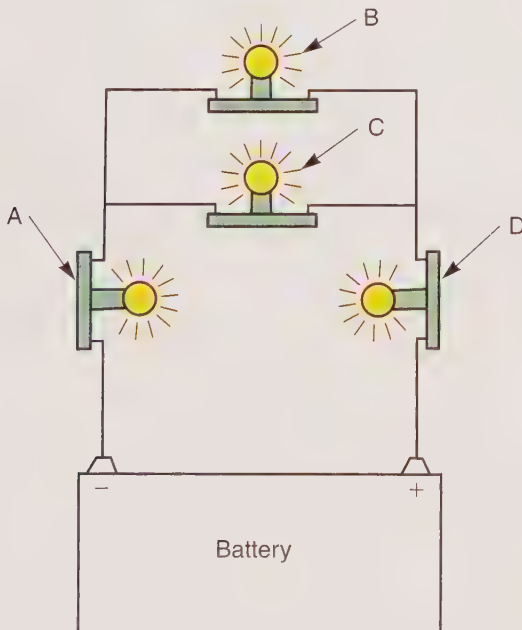


Figure A-9. A series-parallel electrical circuit. Lights A and D are in series. Lights B and C are in parallel.

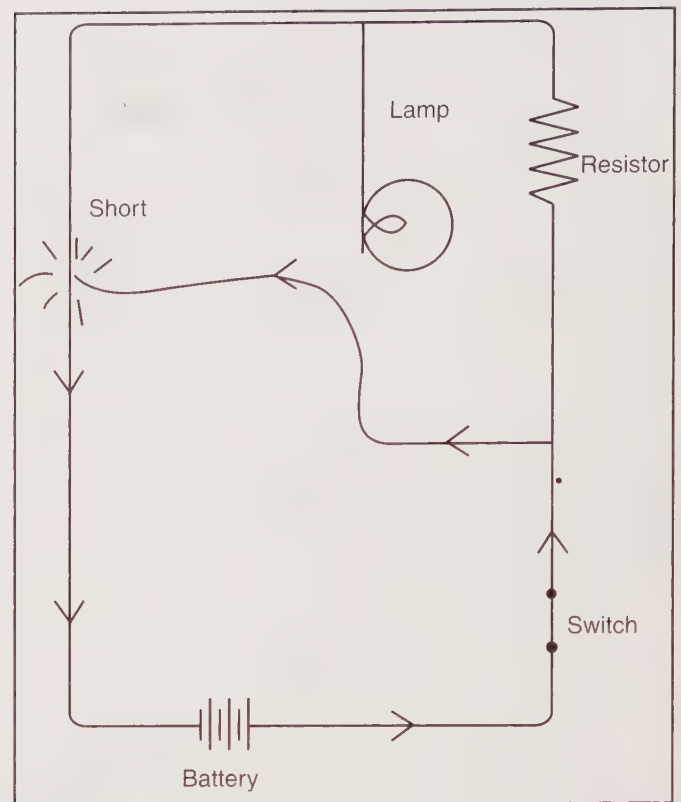


Figure A-10. A short circuit. Note that electrical current is flowing directly to ground (vehicle frame).

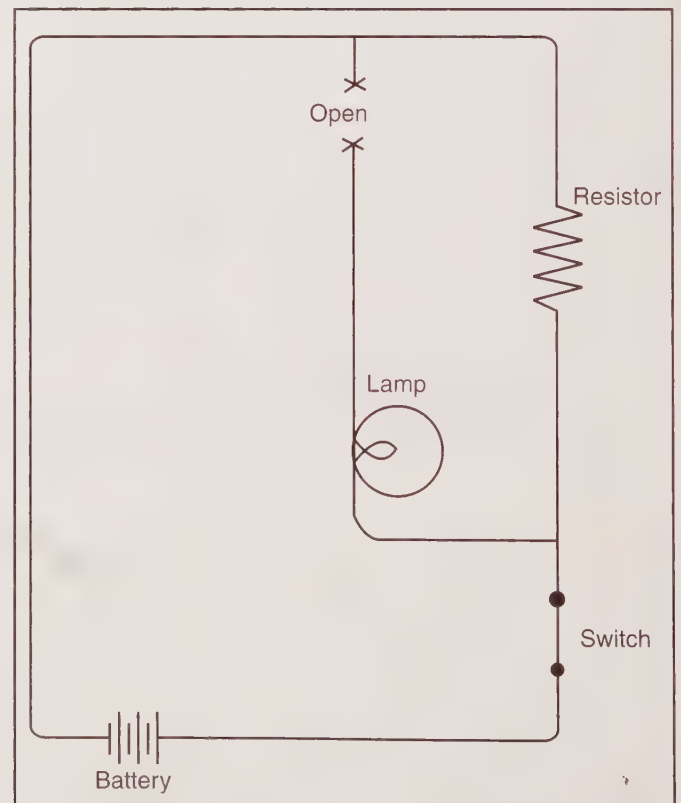


Figure A-11. An open circuit. This open circuit is caused by a break in the wiring.

caused by corrosion or overheating. The high resistance may cause the circuit to stop operating or possibly catch fire at the connection.

Electromagnetism

There is a well-defined relationship between electricity and magnetism. When a material is **magnetic**, the electrical charges of its electrons are aligned to create a force that extends outward from the material. A magnetic material attracts iron and metals that contain iron. Some materials are naturally magnetic, while others can be magnetized by electricity. When current flows in a wire, the electrons start moving in the same direction. Electron movement creates a magnetic field around the wire as long as current is flowing. When the wire is wound into a coil and current is flowing through the wire, the magnetic fields of each wire loop combine to create a very strong magnetic field. The combination of the current flow, coil winding, and a metal core is called an **electromagnet**, **Figure A-12**. The iron core helps to increase field strength and may be movable. The magnetic field created may be used to move linkages or open electrical contacts. Electromagnets are the basic component of solenoids, relays, and motors.

When a wire moves through a magnetic field or a magnetic field moves through a wire, the effect of the field on the electrons in the wire causes them to begin moving. This creates current to flow in the wire. This process is called **induction** and is how current is produced in wheel speed sensors. In wheel speed sensors, the sensor wires are stationary and teeth on the axle move. The teeth create a magnetic fluctuation, or movement, in a permanent magnet built into the sensor. This fluctuation induces AC current in the sensor wiring.

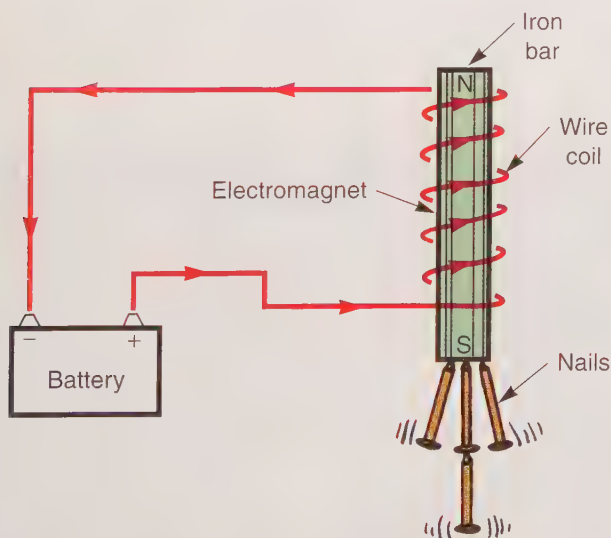


Figure A-12. An electromagnet. As current passes through the wire coil surrounding the iron bar, the bar becomes a magnet. The nails will adhere to the bar until current flow stops. The nails will then drop off the bar.

The relationship between electricity and magnetism is called **electromagnetism**. Electromagnetism is used to operate many electrical devices on the vehicle. These devices will be discussed later in this appendix.

Vehicle Wiring and Electrical Components

The modern automotive electrical system is a complex arrangement of wiring and electrical components. The electrical system must produce electricity and deliver it to the proper places; protect circuits from damage; reduce or increase voltage; change electricity into light, motion, or heat; and use electricity to control the movement of liquids and gases. The construction, operation, and use of devices to accomplish this are discussed in the following section. The operation and function of electronic devices will be discussed later in this chapter.

Wiring

Most automotive wiring is made of copper, aluminum, or aluminum coated with copper. Wires are plastic coated and installed into wrapped assemblies called **harnesses**, **Figure A-13**. For easier circuit tracing, the insulation of every vehicle wire is given a specific color. This is called **color coding**. Modern vehicles have many wires, and it is necessary to increase the number of available colors by adding a stripe or stripes of contrasting colors to the original insulator color. Service literature contains schematics, which show all wires and their colors.

On most vehicles, there is no return wiring from various electrical units back to the battery. The vehicle

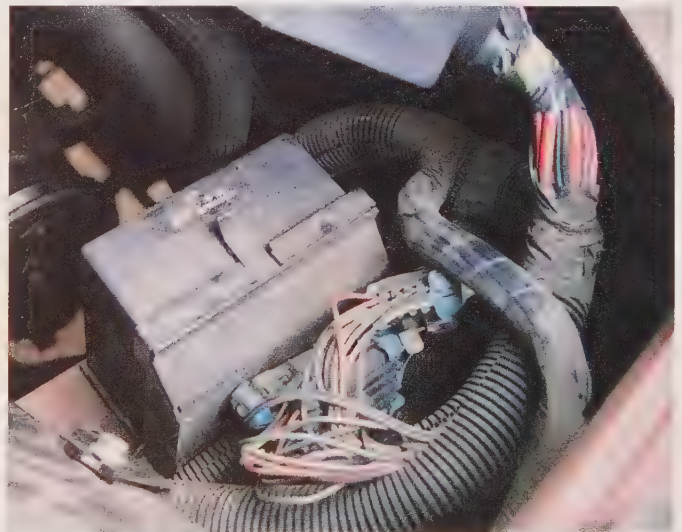


Figure A-13. Many single wires are enclosed in a wiring harness. The wiring harness protects the wires and makes electrical connections easier.

frame forms the return, or **ground**, wire. On all modern vehicles, the negative terminal is the ground terminal. The battery, charging system, and all other electrical devices have their negative terminal wired to the vehicle frame and body. The battery negative cable is attached to the engine block. The body and chassis may be grounded directly to the battery through a smaller ground cable attached to the negative post, or they may be grounded to the engine block by one or more ground straps.

Wire size

All wires have some resistance and lose some electrical power as heat. It is important that the wire in a circuit be large enough to carry the rated amperage without overheating. At the same time, the wire should not be larger than necessary. **Wire gauge** is the rating system for wire diameter. The larger the gauge number, the smaller the wire. Wire gauge is measured in AWG (American Wire Gauge) or metric sizes. Note that the gauge refers only to the thickness of the wire itself, not the thickness of the insulation. Typical wire gauges are shown in **Figure A-14**. Wire gauge shows the highest amperage that can be carried by a particular wire without overheating. The

AWG #	Diameter in Inches	Diameter in mm
30	0.01	0.254
29	0.0113	0.287
28	0.0126	0.32
27	0.0142	0.361
26	0.0159	0.404
25	0.0179	0.455
24	0.0201	0.511
23	0.0226	0.574
22	0.0253	0.643
21	0.0285	0.724
20	0.032	0.813
19	0.0359	0.912
18	0.0403	1.02
17	0.0453	1.15
16	0.0508	1.29
15	0.0571	1.45
14	0.0641	1.63
13	0.072	1.83
12	0.0808	2.05
11	0.0907	2.3
10	0.1019	2.6
8	0.1285	3.3
6	0.1620	4.1
4	0.2043	5.2
2	0.2576	6.5
1	0.2893	7.3
0	0.3249	8.2
00	0.3648	9.3
000	0.4096	10.4

Figure A-14. American Wire Gauge sizes compared to metric wire sizes.

largest gauges (smallest gauge numbers) are used to connect the battery to the vehicle starter. To further reduce resistance, losses, wires carrying high amperages are designed to be as short as possible.

Plug-in connectors

Most connectors on modern vehicles are plug-in types. A **plug-in connector** has male and female ends, which are plugged into each other. Connectors having more than one wire are called multiple connectors. Many service manuals refer to a specific connector by the number of wires it contains, such as a 12-wire connector or a 23-wire connector. Modern connectors are shaped so that they cannot be assembled incorrectly, or there are aligning lugs and slots on each side of the connector.

Modern plug-in connectors are often thoroughly sealed to keep out moisture and corrosion, **Figure A-15**. Since many vehicle electronic components operate on very low voltages, a small increase in resistance due to moisture and corrosion can affect circuit operation.

A few connectors may be screw terminals, or bolts, which pass through a terminal eye to form a connector, **Figure A-16**. These connectors are usually used to connect a ground strap to the vehicle body or to connect circuits with very high current loads, such as the starter and charging system.

Wiring Schematics

A **schematic**, or **wiring diagram**, is a drawing showing electrical units and the wires connecting them. Schematics also show wire colors and terminal types. Use of the schematic allows the technician to trace out defective components in the wiring system. Many vehicle manufacturers break down the overall vehicle wiring into separate circuit diagrams.

Schematics use symbols to represent electrical devices. There is some variation in the use of these symbols. Some

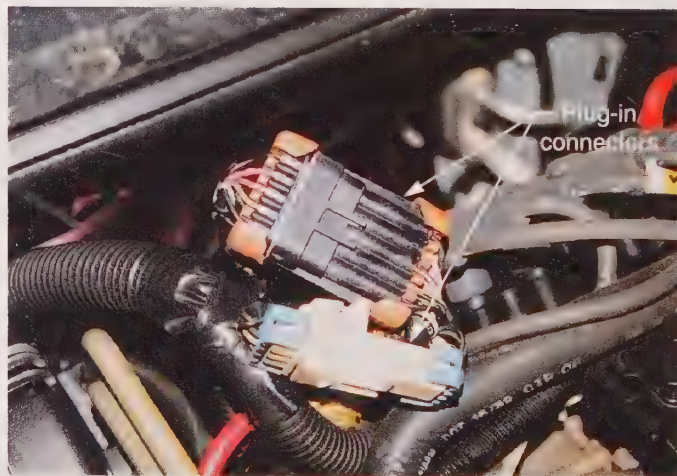


Figure A-15. Plug-in connectors are sealed to prevent moisture from entering and causing corrosion.



Figure A-16. A typical screw terminal. The bolt passes through the wire terminal eyes.

schematics have a combination of company-specific and standardized symbols. **Figure A-17** illustrates some symbols widely used in automotive electrical diagrams.

Circuit Protection Devices

Short circuits or defective components that draw too much current can cause excessive current flows. To protect vehicle circuits from damage due to excessive current flows, **circuit protection devices** are used. These include fuses, fusible links, and circuit breakers. All electrical circuits, except the starter and alternator, will have a circuit protection device.

Fuses

Fuses are made of a soft metal that melts when excess current flows through them, before the current can damage other components or circuit wiring, **Figure A-18**. Most fuses are installed in a **fuse block** usually located under the dashboard or in the glove compartment. A melted, or blown, fuse must be replaced.

Fusible links

A **fusible link** is a length of wire made of soft metal. It operates in the same manner as a fuse, melting when excess current flows, **Figure A-19**. Fusible links are usually installed in the main wiring leading from the battery or starter solenoid to the main electrical circuits. Both a fuse in the fuse box and a fusible link ahead of the box may be used to protect a circuit.

Circuit breakers

Circuit breakers consist of a contact point set attached to a bimetallic strip. The bimetallic strip bends as it heats up, **Figure A-20**. When it becomes hot enough, it bends as

much as necessary to open the point set and break the circuit. When the strip cools off, it straightens out and allows the points to close. The advantage of the circuit breaker is that it can reset itself.

Switches

To control the flow of electricity through a circuit, a **switch** is used. A switch is a device containing internal electrical contacts, which are positioned by some external force. Closing the contacts causes current to flow through the switch. Opening the contacts causes current flow to stop.

The vehicle driver manually operates switches such as the headlight, ignition, windshield wiper, and air conditioner/heater switches. Other switches, such as the brake and backup light switches, are operated as a result of other driver actions. Engine or transmission operating conditions activate some switches. Examples are oil pressure and coolant temperature switches.

Solenoids and Relays

Some electrical components are electromagnetic control devices. Electricity creates a magnetic field, which causes movement of a metal part. In a **relay**, the magnetic field closes one or more sets of electrical contacts, causing electrical flow in a circuit. This is useful when switching high-current devices, such as motors or resistance heaters, without excessive lengths of heavy wire. In a **solenoid**, the magnetic field performs a mechanical task, such as opening or closing a valve.

Motors

To turn electricity into rotation, **motors** are needed. Motors consist of a central **armature** made of many loops of wire. Surrounding the armature are **field coils**. The field coils produce a magnetic field. Current flows through the armature windings. By controlling the direction of the current flowing through the armature windings, the armature can be made to turn inside the field windings. Refer to **Figure A-21**.

Electric motors are found throughout the vehicle, including the starter motor, heater blower motor, windshield wiper motor, power window, seat, and antenna motors, and small motors which provide air pressure for the suspension system.

Resistors

Resistors are placed in a circuit to reduce current flow. They are made of carbon or various metals that create extra resistance to the flow of electrons. This reduces current flow. Resistors are commonly used to reduce motor speeds and protect other circuit components. Some resistors are **variable resistors**. The resistance of a variable resistor can be changed by mechanical linkage.

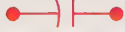
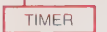
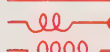
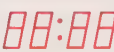
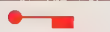
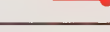
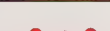
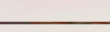
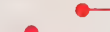
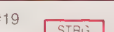
Legends of Symbols Used on Wiring Diagrams			
	Positive		Connector
	Negative		Male Connector
	Ground		Female Connector
	Fuse		Denotes Wire Continues Elsewhere
	Gang Fuses with Bus Bar		Denotes Wires Goes to One of Two Circuits
	Circuit Breaker		Splice
	Capacitor		Splice Identification
	Ohms		Thermal Element
	Resistor		Timer
	Variable Resistor		Multiple Connector
	Series Resistor		Optional Wiring with Wiring without
	Coil		"Y" Windings
	Step Up Coil		Digital Readout
	Open Contact		Single Filament Lamp
	Closed Contact		Dual Filament Lamp
	Closed Switch		L.E.D.—Light Emitting Diode
	Open Switch		Thermistor
	Closed Ganged Switch		Gauge
	Open Ganged Switch		Sensor
	Two Pole Single Throw Switch		Fuel Injector
	Pressure Switch		Denotes Wire Goes through Bulkhead Disconnect
	Solenoid Switch		Denotes Wire Goes through Steering Column Connector
	Mercury Switch		Denotes Wire Goes through Instrument Panel Connector
	Diode or Rectifier		Denotes Wire Goes through Grommet to Engine Compartment
	Bi-Directional Zener Diode		Denotes Wire Goes through Grommet
	Motor		Heated Grid Elements
	Armature and Brushes		

Figure A-17. Various electrical symbols on one vehicle manufacturer's wiring diagrams. Learning the various symbols will improve your ability to use and understand wiring diagrams. (Chrysler)

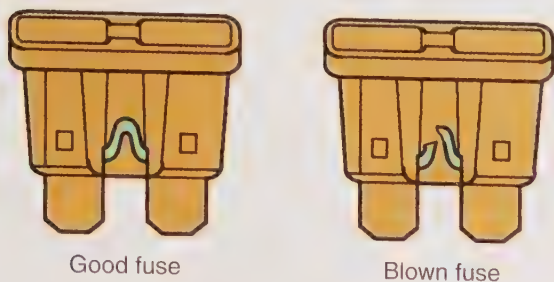


Figure A-18. An example of a good fuse and a blown fuse.

Capacitors

To damp out voltage fluctuations and control electronic frequencies, **capacitors** are often used. The capacitor serves as a trap for voltage surges (sometimes called spikes) before they can affect radio and computer circuits. Almost all modern electrical devices contain capacitors to reduce voltage surges. Modern capacitors are very small and have the same capacity as older models. They are called **chip capacitors**.

Vehicle Electronics

Semiconductor Materials

All modern automotive computers and other electronic devices depend on the use of materials known as **semiconductors**. Semiconductors are made of silicon or germanium with small impurities to cause them to be either conductors or insulators, depending on how voltage is directed into them. Semiconductors change at the atomic level, depending on how their electrons are affected. Common semiconductors are diodes and transistors.

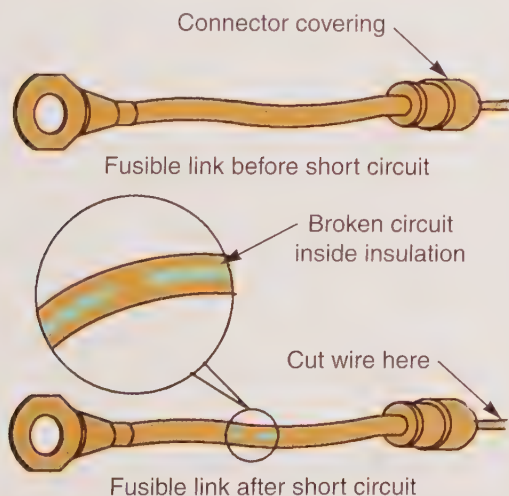


Figure A-19. Good and damaged fusible links. Never replace a fusible link, fuse, or circuit breaker using a piece of wire. A fire may result.

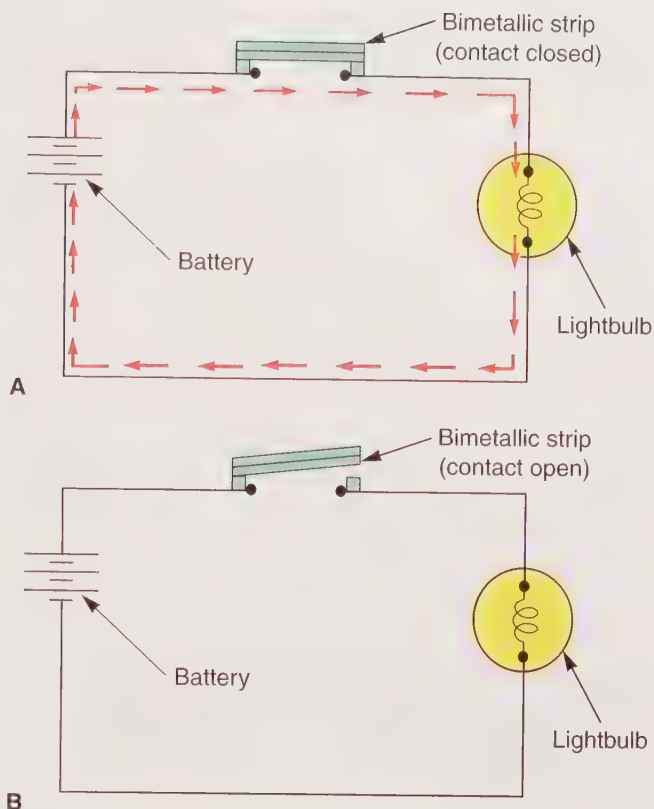


Figure A-20. A circuit breaker with a closed contact and a circuit breaker with an open contact. A—When a circuit is functioning normally, the bi-metal strip remains cool and straight and the contact remains closed. B—When there is an excess flow of current due to a faulty component, the bi-metal strip overheats and bends away from the contact point, opening the circuit.

Diodes

Diodes are semiconductors that allow current to flow in one direction only. Diodes are one-way check valves for electricity. The diode is a conductor or an insulator depending on which way the current tries to flow. Diodes are used in alternators to change alternating current into direct current to charge the battery. Diodes can also be used to prevent voltage surges, either by being installed inside the computer or in the wiring harness to some high current devices. Diodes in these applications prevent reverse current surges when the component is turned on or off.

Transistors

A **transistor** is a semiconductor device used as a switch or amplifier. Transistors can carry heavy current but are operated by very low currents. When a small amount of current is sent to one part of the transistor, it becomes a conductor and much heavier current can flow through another part. When this small amount of current is removed, the transistor becomes an insulator and the heavy current flow stops. Transistors are much more reliable than mechanical contacts or vacuum tubes, and transistors have largely replaced these older components. Transistors used in computers are usually too small to be

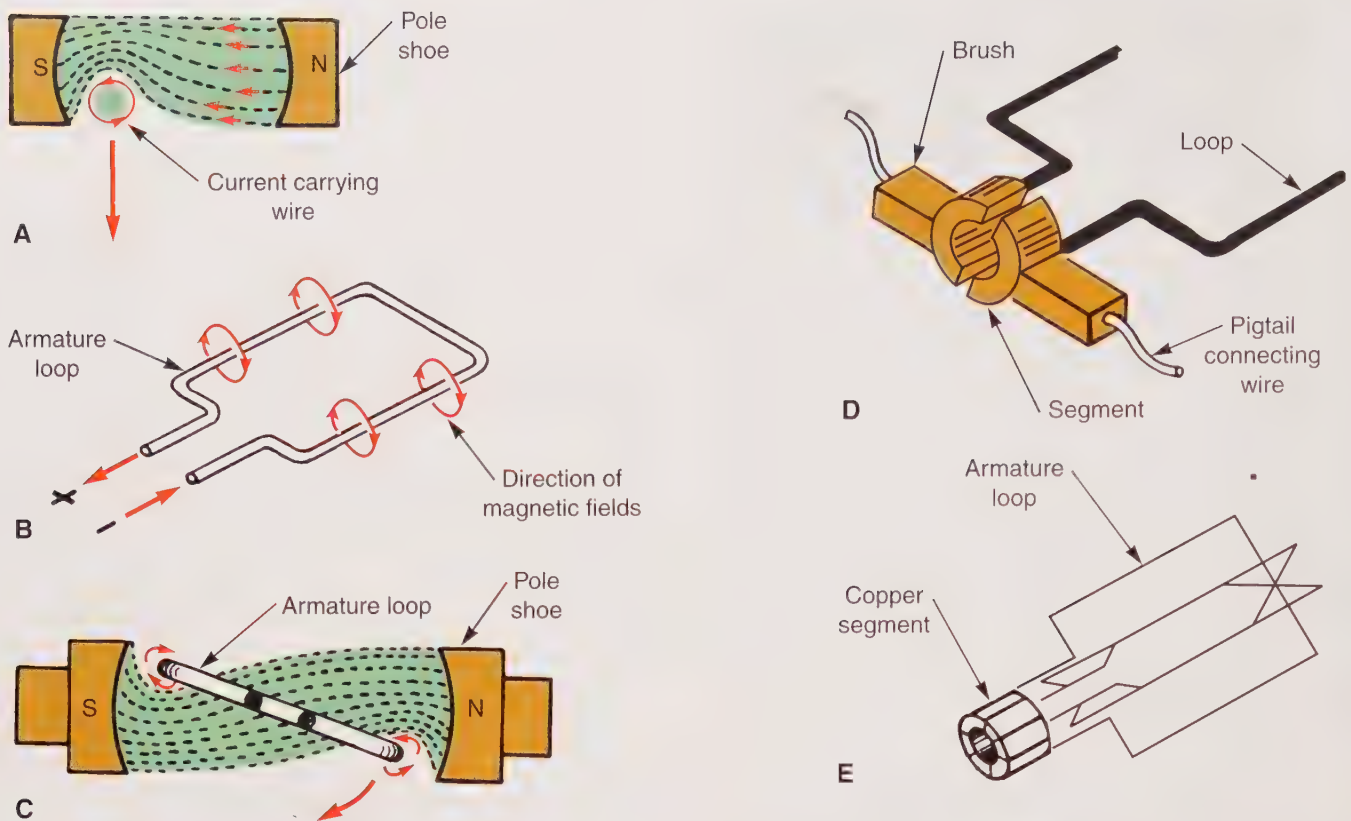


Figure A-21. An electric motor in various stages of construction. A—Current-carrying conductor in a magnetic field. The field around the wire (see small arrows) will oppose that of the pole field. This will cause the wire to be forced out in the direction of arrow A. B—Armature loop. Note the direction of the magnetic field on each side of the loop. C—The armature loop will rotate. Each side of the loop has a field moving in opposite directions. These fields oppose the pole shoe field causing the loop to rotate. D—Commutator segments. In an actual motor, many loops and segments are used. Each segment is insulated from the shaft and the other segments. E—Many loops are required. Additional loops will increase power or torque of the motor.

seen. Large transistors designed to carry heavy current loads are called **power transistors**.

Vehicle Computers

The modern automotive computer is a complex device that can operate many vehicle systems. It is made up of a collection of electronics parts and circuits. All modern cars and trucks have one or more computers. All vehicle computers have some common operating features, which are discussed in the following section.

Computer Circuits

Many diodes and transistors, as well as chip capacitors, resistors, and other parts, are combined onto a large complex electronic circuit by etching the circuitry on small pieces of semiconductor material. A circuit made by this process is called an **integrated circuit**, or **IC**. The IC also contains resistors, capacitors, and other electronic devices. Modern ICs, sometimes called **chips**, or **microprocessors**, can control many vehicle functions.

Control Loops

The microprocessors that make up a modern computer can perform control operations based on their ability to process input messages and issue output commands. This ability allows them to operate as part of a **control loop**, **Figure A-22**. A control loop can be thought of as a circle of causes and effects, which is used to operate part of the vehicle, such as a height control suspension. When the control loop is operating, the **input sensors** furnish information to the computer, which makes output decisions and sends commands to the **output devices**. The operation of the output devices affects the operation of the vehicle system, causing changes in the readings furnished by the input sensors. There is a continuous loop of information from the input sensors, to the computer, to the output devices, to the vehicle system, and back to the input sensors. Computers operate many control loops at the same time.

Main Computer Sections

All automotive computers contain two main sections: the **central processing unit (CPU)** and the **memory**. The

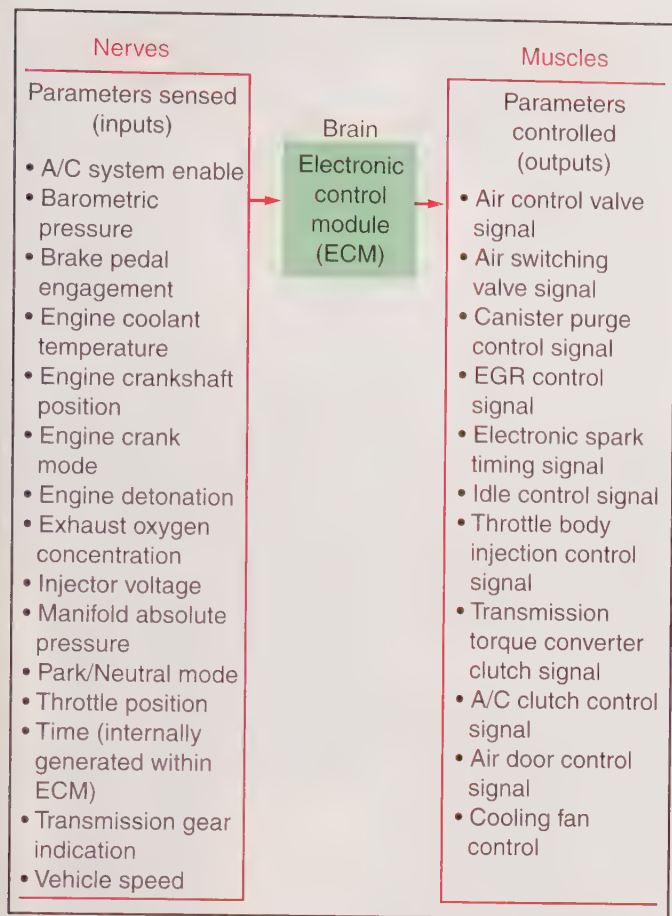


Figure A-22. The computer operating input devices are the sensors (nerves). Information from the sensors goes to the ECM (electronic control module), or the brain. The brain (ECM) controls the output devices (muscles). (General Motors)

CPU and memory are built into the control module, and the entire module must be replaced if either is defective. The construction and operation of these two sections is explained in the following section.

Central processing unit

The **central processing unit** is the section of the computer that receives the input sensor information, compares this information with the information stored in memory, performs calculations, and makes output decisions. The

CPU may contain several microprocessors, as well as other electronic parts.

Memory

The two basic types of computer memory used in the control module are **read only memory (ROM)** and **random access memory (RAM)**. The ROM contains permanent operating instructions and specifications for the system. This information is installed in the ROM at the time of manufacture. The ROM has a permanent memory that will be retained if the battery is disconnected or the system fuse is removed. The information in PROM (programmable read only memory) is similar to that in ROM. However, the information in PROM can be changed. On older vehicles, the PROM is a removable chip, which can be replaced. On new vehicles, a variation of the PROM called an EPROM (erasable programmable read only memory) or a flash EPROM is used. Some of the information in the EPROM can be replaced by erasing and reprogramming.

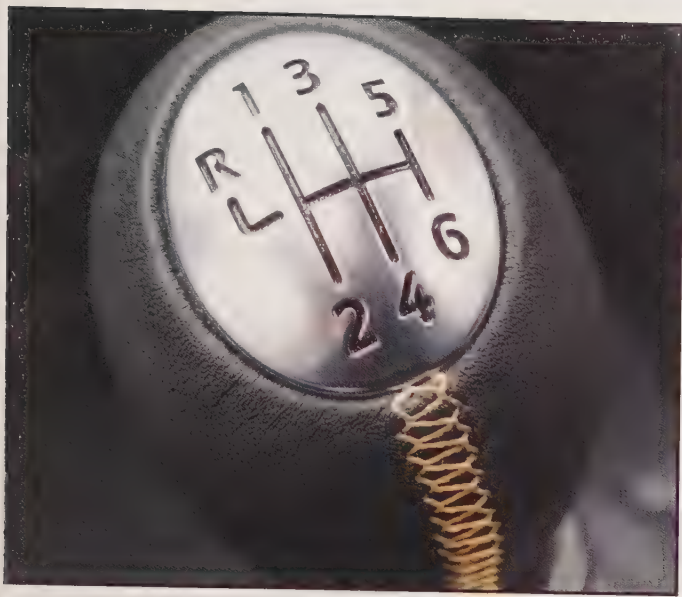
The random access memory (RAM) is a temporary storage place for data from the input sensors. As information is received from the sensors, it is temporarily stored in RAM, overwriting any old information. The computer constantly receives new signals from the input sensors as the vehicle is driven. The RAM has a temporary, or volatile, memory. If the battery cable or system fuse is removed, all data in the RAM will be erased, including trouble codes.

Computer Diagnostic Outputs

In addition to operating the output devices, the computer provides a **diagnostic output** to the technician. This consists of a dashboard-mounted light to indicate that a problem is present and a diagnostic connector or data link connector for retrieving diagnostic information. When a system defect occurs, the control module saves information about the defect in memory. This information takes the form of a **trouble code**. On vehicles up to 1995, trouble codes are 2- or 3-digit numbers corresponding to a specific defect. On newer vehicles with the OBD II system, the trouble code format consists of one letter and four numbers. To determine whether any trouble codes are present, the technician must use a **scan tool** to cause the computer to enter the **self-diagnosis** mode and retrieve trouble codes.



Look closely at the cab of this vehicle. How many items can you point out that are drawing on this vehicle's electrical system? (Ford)



Appendix B

Scan Tools

Scan Tool Purposes

To get the most from the self-diagnostic capabilities of electronically controlled drive train components, you must use a **scan tool**. The following appendix is an overview of the purpose, construction, and use of scan tools. It provides the information needed to effectively use a scan tool when diagnosing problems in the drive train as well as in other vehicle systems.

The most obvious use of a scan tool is to retrieve diagnostic trouble codes. The codes appear as numbers or alphanumeric (numbers and letters) characters on the scan tool's screen.

Many scan tools can be used to perform other diagnostic activities. A scan tool can be used to monitor the operation of the input sensors, ECM (on-board computer), and output devices. These readings can be compared with factory specifications to determine whether a component is defective. For more accurate diagnosis, some newer scan tools can display the waveform (scope pattern) of the device being monitored.

Scan tools can also be used to override the control module and to directly operate an output device, such as a motor or solenoid. Forcing an output device to operate allows the technician to determine the condition of the output device and its related wiring.

In some systems, a scan tool can be used to reprogram the ECM. This is done to update the ECM based on new information supplied by the manufacturer.

Scan Tool Construction and Usage

Scan tools are small and light enough to be handheld. All scan tools have a **keypad**, which contains a set of

function keys used to select the various functions. Typical function keys are the Enter and Exit keys, arrow keys, and number keys. Many scan tools have specialized keys to access specific diagnostic areas or to communicate with a remote computer or printer.

The scan tool's **display screen** displays trouble codes and other diagnostic results, and may also display a **menu**. The menu shows all the possible scan tool functions, or **diagnostic routines**. The technician can pick one of these routines to begin using the scan tool. See **Figure B-1**.

Some scan tools have indicator lights to tell the technician that the scan tool is operating, what mode the system is operating in, and whether there is an obvious system defect.

Cables and adapters are provided with the scan tool. These allow it to be attached to one or more diagnostic connectors installed on the vehicle. Some scan tools also have battery clips or a cigarette lighter adapter to allow them to use the vehicle's battery as a power source. Typical cables and adapters are shown in **Figure B-2**. A few scan tools have an internal backup battery.

Types of Scan Tools

Some older scan tools can be used with the computer control systems installed on only one manufacturer's vehicles and cannot be used to diagnose the systems of other manufacturers. These are called **dedicated scan tools**. The earliest types of these tools can be used for trouble code retrieval only. Later versions can perform other diagnostic functions, but only on the vehicles they are programmed for.

Generic scan tools can be used to diagnose the systems of many different manufacturers. These scan tools use specialized cartridges that must be changed to match the vehicle being worked on. The scan tool may also have

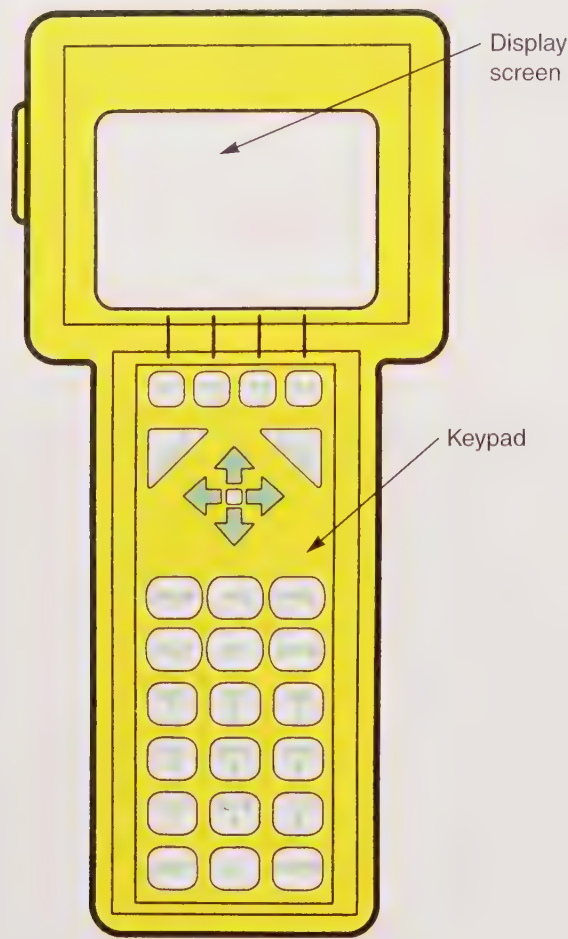


Figure B-1. Scan tools come in a variety of sizes and capabilities. Note the location of the keypad and the display screen. (Chrysler)

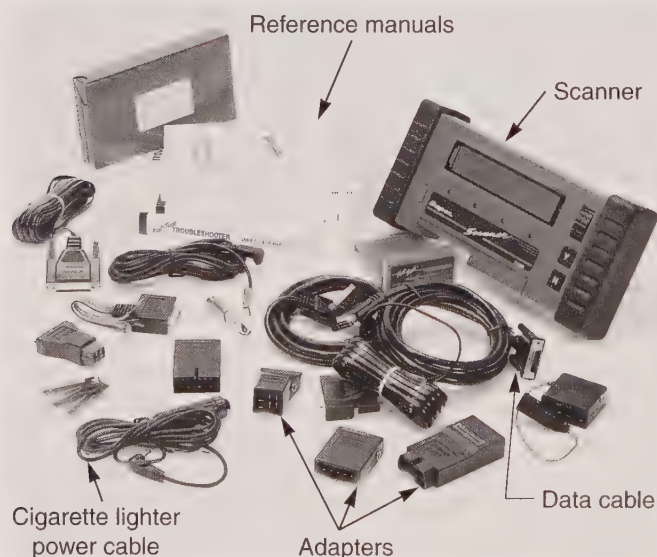


Figure B-2. This scan tool comes with several cables and adapters, allowing it to be used on a wide variety of vehicles. (Snap-on Tools)

adapter cables, allowing it to be plugged into various diagnostic connectors. Some scan tools can be updated by an interface with a desktop PC computer or over a phone line to the manufacturer. Scan tools with this feature have a special terminal that can be connected to a phone line.

Most of the latest scan tools are **bi-directional**. A bi-directional scan tool can retrieve information from the vehicle's computer and send data to the computer. This ability to transfer data two ways allows the scan tool to operate output devices for diagnosis and to reprogram the computer if updates are necessary.

The diagnostic link connector (usually called a DLC) design and trouble code formats of earlier ECMs vary from manufacturer to manufacturer. However, after the 1996 model year, all vehicle manufacturers were required to use the OBD II trouble code format. All OBD II systems use a standard 16-pin DLC, and generic scan tools can retrieve trouble codes from any OBD II equipped vehicle without special cartridges.

Rules for Scan Tool Usage

A scan tool may look harmless, but can create a very dangerous situation if it is used or placed in the vehicle improperly. The following are several hints for using scan tools properly and safely:

- ☐ Make sure the cables are located away from the accelerator, brake pedal, and all moving parts.
- ☐ Do not shut off the ignition key unless prompted to do so by the scan tool. If the ignition key is shut off, any scanned information may be lost.
- ☐ Do not disconnect the scan tool cable from the DLC during any programming or learn procedure. Damage to the computer may result.
- ☐ Never remove the scan tool cartridge or program card from the scan tool while power is on.
- ☐ Do not expose the scan tool to direct sunlight for extended periods, as it can damage the display screen.
- ☐ Never hang the scan tool from the rearview mirror. This will place it in a location where the cables or the scan tool itself may become caught in the steering wheel. The tool's weight may pull the rear view mirror off its mounting, possibly damaging the mirror or the windshield.
- ☐ If the DLC is located under the hood (some older vehicles only), use an extension cable that allows the scan tool to be located inside the passenger compartment or use a chassis dynamometer.
- ☐ Be aware of special operating conditions that exist while the scan tool is connected to the DLC. For example, some ABS systems are disabled any time a scan tool is connected to the DLC. The scan tool will usually warn you if certain systems or vehicle functions will be disabled.

- ❑ Never drive and monitor scan tool functions. You will not be able to devote full attention to either the scan tool display or the road. If it is necessary to monitor scan tool functions during a road test, have another technician or shop foreman drive the vehicle for you.
- ❑ Do not perform any actuator or scan tool intrusive tests while driving the vehicle. Doing so may disable a vital safety system, such as the brakes. Only use the scan tool's system monitor and snapshot features during a road test.
- ❑ If you must leave the vehicle for more than a few minutes, disconnect the scan tool from battery power. Scan tools draw a great amount of power and can drain the battery if the engine is not running.

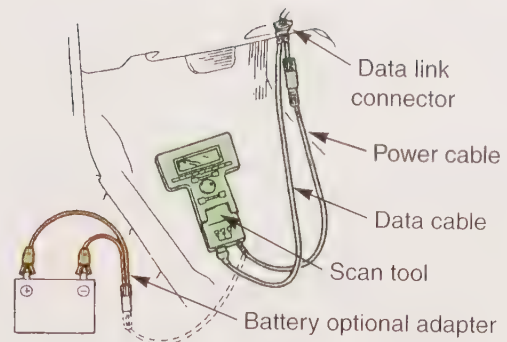
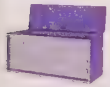


Figure B-4. This particular scan tool has cable connections to battery power and to the vehicle's diagnostic link connector (DLC).

Connecting the Scan Tool

Locate the vehicle's DLC. It will most likely be in the passenger compartment or the engine compartment. Check the service manual for the exact location, as some older vehicles use several DLCs for various on-board computer systems.



Note: OBD II DLCs are always located below the instrument panel near the steering column.

Look at the connector and determine which cable and/or adapter is needed. Unpack the scan tool and connect the proper cable and adapter, if needed. If the scan tool requires one, load the correct program cartridge into the tool, **Figure B-3**.

Carefully plug the scan tool's data cable/adapter into the DLC. The cable should connect to the DLC easily. If resistance is encountered, remove the cable and check for bent pins. Make sure you are using the correct adapter. If necessary, connect the scan tool to battery power, **Figure B-4**. Many scan tools draw power from the cigarette lighter or directly from the battery. All OBD II scan tools draw power from pin 16 of the DLC. A CAN adapter may be needed to allow the scan tool to communicate with the faster ECMs on newer vehicles.

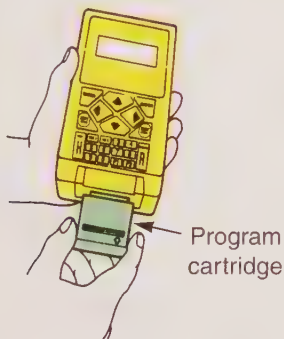


Figure B-3. Make sure you plug in the program cartridge before connecting the scan tool to power. The cartridge should fit securely, but it should not be tight in its slot. (OTC)

Once the scan tool is connected to power, the display screen should light, along with any indicator LEDs. In some cases, the scan tool will perform a **power-on self-test (POST)**, which verifies that it is operating properly.

Inputting Vehicle Data

The next step, in most cases, is to enter data about the vehicle into the scan tool. The scan tool will request that you enter information on the vehicle make, model, engine type, transmission type, and options. Usually, the scan tool will receive this information by asking you to enter certain letters and numbers from the vehicle identification number (VIN). If the VIN is not on the repair order, it should be located on the dash, on a sticker inside one of the door-jamb, or in the engine compartment. If you make a mistake at any point, use the arrow or exit keys to back up. OBD II scan tools will access the VIN and other information directly from the ECM when the engine is started or the ignition switch is placed in the ON position.

Once the necessary vehicle information has been entered, the scan tool will present the first of many menu screens. From here, you will be able to select the system you wish to monitor or the test you wish to perform.

Scan Tool Menu Functions

The first display you should see is a main menu screen that lists several choices, based on the scan tool's programming. In most cases, the menu is a list of general scan tool functions. Use the arrow keys to select the function you need. Then press the **Enter** or **Yes** key to proceed to the next screen.

The next menu screen will ask which specific computerized system you want to diagnose. It will list all the computerized systems available on that particular vehicle make and model. Once again, you should scroll to and select the system where the problem is most likely located. See **Figure B-5**.

Once the selection of a system is made, a third menu will ask which particular test or feature you would like to use. This menu is normally referred to as the **Diagnostic menu**.

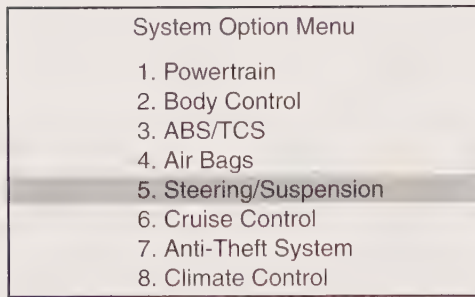


Figure B-5. By using the arrow keys, you can select menu options. A shaded box often appears over the selected option as you scroll through the menu.

It is from this menu that you will perform the majority of your selections, **Figure B-6**. In most cases, the first step should be to see if any trouble codes have been stored in the computer's memory.

Reading Diagnostic Trouble Codes

Trouble codes are usually either two-digit numbers or five-digit alphanumeric codes. Some scan tools may present trouble codes in both formats, if applicable. However, do not attempt to correlate these trouble codes on your own. When the scan tool reads codes, it will give the code number, as well as an explanation of the problem. If there is more than one code stored, the scan tool will present them in numeric order, from lowest to highest. Write down each code and the problem as indicated by the scan tool.

After all the codes are presented, the scan tool will ask if you want to see the trouble code history. The history indicates the number of times each code has been set within a certain number of keystarts or engine warm-ups. See **Figure B-7**. Even if only one code has been stored, select this function, as it will give you an indication of whether the code is hard or intermittent. Select **DTC History** and press the **Enter** key.

Using the Freeze Frame Data

Vehicles equipped with OBD II computer systems have an additional feature that saves, or freezes, sensor and

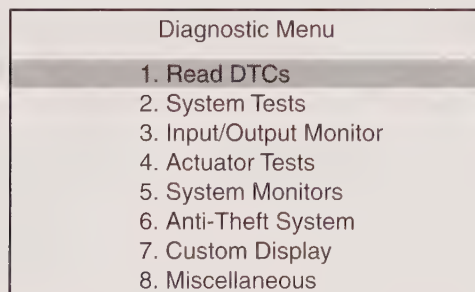


Figure B-6. The diagnostic menu gives you a host of choices to begin your scan tool diagnosis. In most cases, the first choice should be to read diagnostic trouble codes.

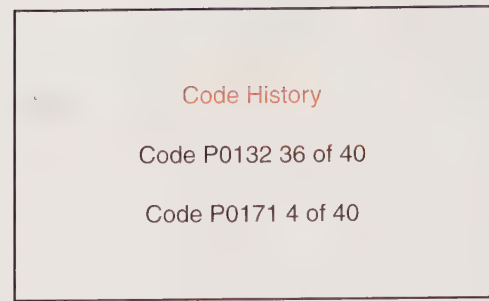


Figure B-7. Code history shows trouble codes in descending order by the number of times each code was set during a specified number of keystarts or engine warm-ups.

output device data when certain trouble codes are stored. This information is called **freeze frame data**.

Freeze frame data can reduce the time needed to diagnose a problem by saving a picture of the sensor/actuator data that existed when the code was set. In the past, it was necessary to reset the computer and road test the vehicle with the scan tool set to the **snapshot** mode. In this mode, the scan tool would record the computer's input and output values at the moment the problem took place. The drawback to this is if the problem did not occur, no data would be captured. Freeze frame shows the data present when the original problem took place.

In some cases, the freeze frame data can be downloaded into the scan tool and kept for comparison to other test readings or for subsequent downloading to a computer mainframe database.

Using Scan Tools to Clear Trouble Codes

After viewing the trouble codes and/or history information, the scan tool will ask if you wish to clear the stored codes. In some cases, there may be a separate menu selection titled **Clear DTC** or **Clear Stored Codes**. Make sure you have written down the code information, trouble code history, and freeze frame information, where applicable. Select **Yes** or **Enter** when prompted to clear codes, **Figure B-8**. After a second, the scan tool will tell you if the codes have been cleared. In some cases, the MIL light may flash while the scan tool is clearing the computer's memory.

Clearing the stored trouble codes also clears the code history, failure record, and freeze frame data. After the scan tool indicates the codes have been cleared, recheck the computer's memory to ensure that the codes have been cleared or a potential hard code has not reset. If no codes are set, drive the vehicle or activate the system that caused the original code(s). Recheck the computer for codes after a few minutes of driving or system operation.

Sensor/Actuator Display

The sensor display feature will show you the major systems the computer monitors. In most cases, you will have three or four selections, **Figure B-9**. The **Sensor Monitor** function shows only the sensor inputs to the ECM

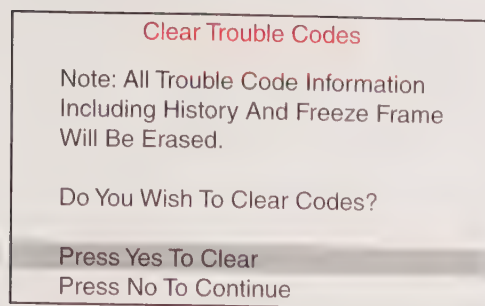


Figure B-8. After writing down the trouble code information, clear the computer's memory and road test the vehicle or operate the system to see if the code resets.

for a particular system. Choosing **Actuator Tests** shows the computer outputs to the actuators and allows you to control their operation. This gives you the ability to check the circuits of certain computer-controlled output devices, reducing or eliminating the need to test the circuits using a meter or test light.

Some scan tools combine the input and output selections into one function. When you select the Sensor/Actuator display function, the scan tool will show you the inputs of all vehicle sensors and its outputs to the actuators in real time. Much of your diagnostic information will be found on these menu screens. Use the **More** key or the arrow keys to scroll through the sensor and actuator readings.

The other selection is the **Custom Display**, which allows you to choose which individual functions you want to see.

Using Scan Tools to Program the Computer

Most new computers use memory chips that are erased and reprogrammed. The scan tool can be used to program these chips and to reset certain ECM and vehicle functions.

Programming is done by downloading the new operating information through the scan tool. The scan tool is first programmed with the vehicle information from a computer or computerized analyzer. The information is then downloaded from the scan tool into the computer. Follow the instructions in the service manual whenever you are programming or reprogramming a computer, **Figure B-10**.

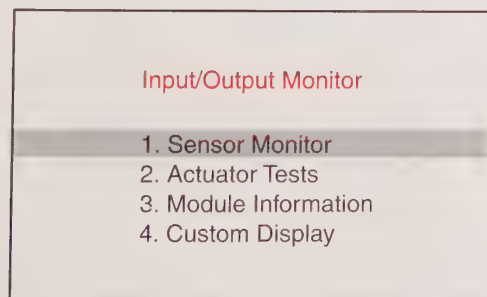


Figure B-9. There are menu options that will allow you to see the sensor inputs and the computer outputs as they occur.

Scan Tool Maintenance

Like all other tools, a scan tool must be cared for properly if it is to provide years of trouble-free service. You will not realize how valuable a scan tool is until it is out for repair due to abuse or neglect.

Keep the scan tool as clean as possible. Wipe it clean of dirt, oil, and grease after each use using a dry shop towel. Never use an abrasive cleanser to clean the scan tool. Clean the display screen and keypad with a nonabrasive glass cleaner applied to a soft, static-free cloth. Clean the cables with a mild soap solution. Never immerse the scan tool in water. While most scan tools have laminated surfaces, they are not waterproof.

Some scan tools are equipped with one or more cooling fans. These fans have a small filter that should be removed and cleaned using warm soapy water. If the filter cannot be cleaned, it should be replaced.

When you are finished using the scan tool, put it back in its case. Remove any external program cartridges, cables, and any adapters and place them in their respective compartments.

Common Scan Tool Usage Problems

If you run into problems when using scan tools, refer to the scan tool's user manual. It contains hints on solving problems encountered while using the scan tool. Some common problems and their causes are listed in the following paragraphs.

Scan Tool Appears to Have No Power

This is the most common problem you will encounter. It is usually caused by a poor external power connection at the cigarette lighter or the battery. Make sure your power connection is clean and tight. If the scan tool draws power from the DLC, make sure the connection is tight and the pins are straight and clean.

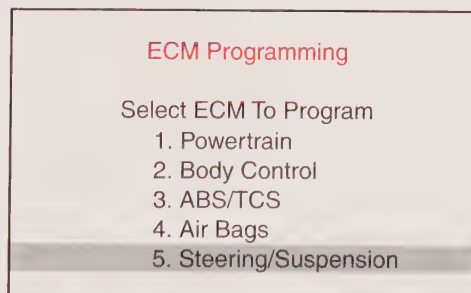


Figure B-10. It is possible to reprogram the computer on certain vehicles. Make sure you are programming the correct computer.

Useful Tables

METRIC/U.S. CUSTOMARY UNIT EQUIVALENTS

Multiply: by: to get: | Multiply: by: to get:

ACCELERATION

feet/sec ²	x 0.3048	= meters/sec ² (m/s ²)	x 3.281	= feet/sec ²
inches/sec ²	x 0.0254	= meters/sec ² (m/s ²)	x 39.37	= inches/sec ²

ENERGY OR WORK (watt-second = joule = newton-meter)

foot-pounds	x 1.3558	= joules (J)	x 0.7376	= foot-pounds
calories	x 4.187	= joules (J)	x 0.2388	= calories
Btu	x 1055	= joules (J)	x 0.000948	= Btu
watt-hours	x 3600	= joules (J)	x 0.0002778	= watt-hours
kilowatt-hrs.	x 3.600	= megajoules (MJ)	x 0.2778	= kilowatt-hrs

FUEL ECONOMY AND FUEL CONSUMPTION

miles/gal	x 0.42514	= kilometers/liter (km/L)	x 2.3522	= miles/gal
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Note:

235.2/(mi/gal) = liters/100km

235.2/(liters/100 km) = mi/gal

LIGHT

footcandles	x 10.76	= lumens/meter ² (lm/m ²)	x 0.0929	= footcandles
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PRESSURE OR STRESS (newton/sq meter = pascal)

inches Hg(60 °F)	x 3.377	= kilopascals (kPa)	x 0.2961	= inches Hg
pounds/sq in	x 6.895	= kilopascals (kPa)	x 0.145	= pounds/sq in
inches H ₂ O(60 °F)	x 0.2488	= kilopascals (kPa)	x 4.0193	= inches H ₂ O
bars	x 100	= kilopascals (kPa)	x 0.01	= bars
pounds/sq ft	x 47.88	= pascals (Pa)	x 0.02088	= pounds/sq ft

POWER

horsepower	x 0.746	= kilowatts (kW)	x 1.34	= horsepower
ft-lbf/min	x 0.0226	= watts (W)	x 44.25	= ft-lbf/min

TORQUE

pounds-inches	x 0.11298	= newton-meters (N-m)	x 8.851	= pound-inches
pound-feet	x 1.3558	= newton-meters (N-m)	x 0.7376	= pound-feet

VELOCITY

miles/hour	x 1.6093	= kilometers/hour (km/h)	x 0.6214	= miles/hour
feet/sec	x 0.3048	= meters/sec (m/s)	x 3.281	= feet/sec
kilometers/hr	x 0.27778	= meters/sec (m/s)	x 3.600	= kilometers/hr
miles/hour	x 0.4470	= meters/sec (m/s)	x 2.237	= miles/hour

COMMON METRIC PREFIXES

mega (M)	= 1 000 000	or 10 ⁶	centi (c)	= 0.01	or 10 ⁻²
kilo (k)	= 1 000	or 10 ³	milli (m)	= 0.001	or 10 ⁻³
hecto (h)	= 100	or 10 ²	micro (μ)	= 0.000 001	or 10 ⁻⁶

CONVERSION CHART

U.S. CUSTOMARY/METRIC UNIT EQUIVALENTS

Multiply: by: to get: | Multiply: by: to get:

LINEAR

inches	x 25.4	= millimeters (mm)	x 0.03937	= inches
feet	x 0.3048	= meters (m)	x 3.281	= feet
yards	x 0.9144	= meters (m)	x 1.0936	= yards
miles	x 1.6093	= kilometers (km)	x 0.6214	= miles
inches	x 2.54	= centimeters (cm)	x 0.3937	= inches
microinches	x 0.0254	= micrometers (μm)	x 39.37	= microinches

AREA

inches ²	x 645.16	= millimeters ² (mm ²)	x 0.00155	= inches ²
inches ²	x 6.452	= centimeters ² (cm ²)	x 0.155	= inches ²
feet ²	x 0.0929	= meters ² (m ²)	x 10.764	= feet ²
yards ²	x 0.8361	= meters ² (m ²)	x 1.196	= yards ²
acres ²	x 0.4047	= hectares (10 ⁴ m ²)		

ha	x 2.471	= acres
km ²	x 0.3861	= miles ²

VOLUME

inches ³	x 16387	= millimeters ³ (mm ³)	x 0.000061	= inches ³
inches ³	x 16.387	= centimeters ³ (cm ³)	x 0.06102	= inches ³
inches ³	x 0.01639	= liters (L)	x 61.024	= inches ³
quarts	x 0.94635	= liters (L)	x 1.0567	= quarts
gallons	x 3.7854	= liters (L)	x 0.2642	= gallons
feet ³	x 28.317	= liters (L)	x 0.03531	= feet ³
feet ³	x 0.02832	= meters ³ (m ³)	x 35.315	= feet ³
fluid oz	x 29.57	= milliliters (mL)	x 0.03381	= fluid oz
yards ³	x 0.7646	= meters ³ (m ³)	x 1.3080	= yards ³
teaspoons	x 4.929	= milliliters (mL)	x 0.2029	= teaspoons
cups	x 0.2366	= liters (L)	x 4.227	= cups

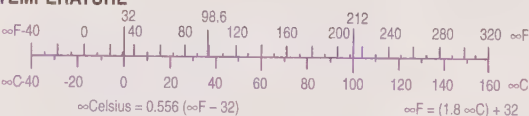
MASS

ounces (av)	x 28.35	= grams (g)	x 0.03527	= ounces (av)
pounds (av)	x 0.4536	= kilograms (kg)	x 2.2046	= pounds (av)
tons (2000 lb)	x 907.18	= kilograms (kg)	x 0.001102	= tons (2000 lb)
tons (2000 lb)	x 0.90718	= metric tons (t)	x 1.1023	= tons (2000 lb)

FORCE

ounces-f (av)	x 0.278	= newtons (N)	x 3.597	= ounces-f (av)
pounds-f (av)	x 4.448	= newtons (N)	x 0.2248	= pounds-f (av)
kilograms-f	x 9.807	= newtons (N)	x 0.10197	= kilograms-f

TEMPERATURE



TAP/DRILL CHART

COARSE STANDARD THREAD (N.C.) Formerly U.S. Standard Thread					FINE STANDARD THREAD (N.F.) Formerly S.A.E. Thread				
Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill	Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	.073	53	0.0595	0	80	.060	³ / ₆₄	0.0469
2	56	.086	50	0.0700	1	72	.073	53	0.0595
3	48	.099	47	0.0785	2	64	.086	50	0.0700
4	40	.112	43	0.0890	3	56	.099	45	0.0820
5	40	.125	38	0.1015	4	48	.112	42	0.0935
6	32	.138	36	0.1065	5	44	.125	37	0.1040
8	32	.164	29	0.1360	6	40	.138	33	0.1130
10	24	.190	25	0.1495	8	36	.164	29	0.1360
12	24	.216	16	0.1770	10	32	.190	21	0.1590
¹ / ₄	20	.250	7	0.2010	12	28	.216	14	0.1820
⁵ / ₁₆	18	.3125	F	0.2570	¹ / ₄	28	.250	3	0.2130
³ / ₈	16	.375	⁵ / ₁₆	0.3125	⁵ / ₁₆	24	.3125	1	0.2720
⁷ / ₁₆	14	.4375	U	0.3680	³ / ₈	24	.375	0	0.3320
¹ / ₂	13	.500	²⁷ / ₆₄	0.4219	⁷ / ₁₆	20	.4375	²⁵ / ₆₄	0.3906
⁹ / ₁₆	12	.5625	³¹ / ₆₄	0.4843	¹ / ₂	20	.500	²⁹ / ₆₄	0.4531
⁵ / ₈	11	.625	¹⁷ / ₃₂	0.5312	⁹ / ₁₆	18	.5625	0.5062	0.5062
³ / ₄	10	.750	²¹ / ₃₂	0.6562	⁵ / ₈	18	.625	0.5687	0.5687
⁷ / ₈	9	.875	⁴⁹ / ₆₄	0.7656	³ / ₄	16	.750	¹¹ / ₁₆	0.6875
1	8	1.000	⁷ / ₈	0.875	⁷ / ₈	14	.875	0.8020	0.8020
¹ / ₁₆	7	1.125	⁶³ / ₆₄	0.9843	1	14	1.000	0.9274	0.9274
¹ / ₄	7	1.250	¹⁷ / ₁₆	1.1093	¹ / ₁₆	12	1.125	¹³ / ₁₆	1.0468
					¹ / ₄	12	1.250	¹¹ / ₁₆	1.1718

BOLT TORQUING CHART

METRIC STANDARD							SAE STANDARD/FOOT POUNDS						
Grade of Bolt		5D	.8G	10K	12K	Size of Socket or Wrench Opening	Grade of Bolt	SAE 1 & 2	SAE 5	SAE 6	SAE 8		
Min. Tensile Strength		71,160 P.S.I.	113,800 P.S.I.	142,200 P.S.I.	170,679 P.S.I.		Min. Tensile Strength	64,000 P.S.I.	105,000 P.S.I.	133,000 P.S.I.	150,000 P.S.I.		
Grade Markings on Head							Markings on Head					Size of Socket or Wrench Opening	
Metric		Foot Pounds				Metric	U.S. Standard	Foot Pounds				U.S. Regular	
Bolt Dia.	U.S. Dec Equiv.					Bolt Head	Bolt Dia.					Bolt Head	Nut
6mm	.2362	5	6	8	10	10mm	1/4	5	7	10	10.5	3/8	7/16
8mm	.3150	10	16	22	27	14mm	5/16	9	14	19	22	1/2	9/16
10mm	.3937	19	31	40	49	17mm	3/8	15	25	34	37	9/16	5/8
12mm	.4720	34	54	70	86	19mm	7/16	24	40	55	60	5/8	3/4
14mm	.5512	55	89	117	137	22mm	1/2	37	60	85	92	3/4	13/16
16mm	.6299	83	132	175	208	24mm	9/16	53	88	120	132	7/8	7/8
18mm	.709	111	182	236	283	27mm	5/8	74	120	167	180	15/16	1.
22mm	.8661	182	284	394	464	32mm	3/4	120	200	280	296	1-1/8	1-1/8

DECIMAL CONVERSION CHART

FRACTION	INCHES	M/M	FRACTION	INCHES	M/M
1/64	.01563	.397	33/64	.51563	13.097
1/32	.03125	.794	17/32	.53125	13.494
3/64	.04688	1.191	35/64	.54688	13.891
1/16	.06250	1.588	9/16	.56250	14.288
5/64	.07813	1.984	37/64	.57813	14.684
3/32	.09375	2.381	19/32	.59375	15.081
7/64	.10938	2.778	39/64	.60938	15.478
1/8	.12500	3.175	5/8	.62500	15.875
9/64	.14063	3.572	41/64	.64063	16.272
5/32	.15625	3.969	21/32	.65625	16.669
11/64	.17188	4.366	43/64	.67188	17.066
3/16	.18750	4.763	11/16	.68750	17.463
13/64	.20313	5.159	45/64	.70313	17.859
7/32	.21875	5.556	23/32	.71875	18.256
15/64	.23438	5.953	47/64	.73438	18.653
1/4	.25000	6.350	3/4	.75000	19.050
17/64	.26563	6.747	49/64	.76563	19.447
9/32	.28125	7.144	25/32	.78125	19.844
19/64	.29688	7.541	51/64	.79688	20.241
5/16	.31250	7.938	13/16	.81250	20.638
21/64	.32813	8.334	53/64	.82813	21.034
11/32	.34375	8.731	27/32	.84375	21.431
23/64	.35938	9.128	55/64	.85938	21.828
3/8	.37500	9.525	7/8	.87500	22.225
25/64	.39063	9.922	57/64	.89063	22.622
13/32	.40625	10.319	29/32	.90625	23.019
27/64	.42188	10.716	59/64	.92188	23.416
7/16	.43750	11.113	15/16	.93750	23.813
29/64	.45313	11.509	61/64	.95313	24.209
15/32	.46875	11.906	31/32	.96875	24.606
31/64	.48438	12.303	63/64	.98438	25.003
1/2	.50000	12.700	1	1.00000	25.400

SOME COMMON ABBREVIATIONS			
U.S. CUSTOMARY		METRIC	
UNIT	ABBREVIATION	UNIT	ABBREVIATION
inch	in.	kilometer	km
feet	ft.	hectometer	hm
yard	yd.	dekameter	dam
mile	mi.	meter	m
grain	gr.	decimeter	dm
ounce	oz.	centimeter	cm
pound	lb.	millimeter	mm
teaspoon	tsp.	cubic centimeter	cm ³
tablespoon	tbsp.	kilogram	kg
fluid ounce	fl. oz.	hectogram	hg
cup	c.	dekagram	dag
pint	pt.	gram	g
quart	qt.	decigram	dg
gallon	gal.	centigram	cg
cubic inch	in ³	milligram	mg
cubic foot	ft ³	kiloliter	kl
cubic yard	yd ³	hectoliter	hl
square inch	in ²	dekaliter	dl
square foot	ft ²	liter	L
square yard	yd ²	centiliter	cl
square mile	mi ²	milliliter	ml
Fahrenheit	F°	square kilometer	km ²
barrel	bbl.	hectare	ha
fluid dram	fl. dr.	are	a
board foot	bd. ft.	centare	ca
rod	rd.	tonne	t
dram	dr.	Celsius	C°
bushel	bu.		

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Glossary

- 4-speed transmission:** Transmission with four forward gears.
- 5-speed transmission:** Transmission with five forward gears. Fifth gear is usually overdrive.
- 6-speed transmission:** Transmission with six speeds (gear ratios) in a compact case. In some instances, both fifth and sixth gears are overdrives.

A

- Abnormal noise:** Unusual sound, such as clunking, popping, or clicking, that is caused by a defective component.
- Additive:** Chemicals added to improve some of the properties, or characteristics, of the original product.
- Adhesives:** Used for holding parts together.
- Admission ticket:** Ticket printed out by ASE test applicant once the payment is made. The applicant must take the admission ticket to the test center when reporting for the test.
- Alignment tool:** Tool used in clutch and transmission work to keep drive train parts in alignment.
- All-wheel drive system:** A type of four-wheel drive system that is in four-wheel drive at all times. A special internal clutch in the transfer case diverts more or less power to the front wheels depending on road conditions.
- Anaerobic sealer:** Sealer that cures to a plastic-like substance in the absence of air.
- Angle gauge:** Device that measures angles between two components or inclinations (angles relative to the plane of reference).
- Annulus gear:** See *Ring gear*.
- Antifriction bearing:** Bearing that uses an assembly of balls or rollers contained within a housing where they are aligned and free to roll. The bearing is pressed in place; however, the one side (inner and outer) is free to move with the rotating member because of the rolling elements.
- Apply spring:** Holds the pressure plate against the clutch disc.
- ASE-certified master technician:** A technician who can pass all the required tests in the automotive, medium/heavy truck, engine machinist, or collision repair/refinishing areas and meets the experience requirements is certified as a in that area.
- ASE-certified technician:** Any person passing one or more of these tests and meeting certain work experience requirements is granted status in the subject covered by that test.
- ASE Preparation Guide:** Free booklet available from ASE to help you sharpen your skills for the ASE tests.

- Automatic four-wheel drive transfer case:** The ECM makes most decisions and the driver does not select the necessary transfer case range.
- Automatic transmission fluid (ATF):** Lubricant oil that has a lower viscosity than gear oils.
- Axial centerline:** Central axis around which rotating parts revolve.
- Axial load:** Parallel to the axis of rotation.
- Axial vibration:** A lengthwise, or back-and-forth, movement of the shaft along its rotational axis.
- Axial bearing:** Any bearing that supports a rotating axle inside of a stationary housing. Usually applies to the antifriction bearings installed on the outer ends of a solid rear axle assembly, but may be used as a term for the bearings in the wheel hubs of an independent rear axle or a front-drive axle.
- Axle collar:** Axles having bearings that are pressed on will have a bearing retainer, or axle collar, to keep the bearing in place.
- Axle end gears:** See *Slide gears*.
- Axle endplay:** Amount of lengthwise movement on an axle.
- Axle flange:** Acts as a wheel hub, providing the mounting surface for the brake drum or rotor and the wheel.
- Axle retainer plate:** Holds the axle and axle bearing to the axle tube.
- Axle shim:** Adjusts the bearing preload to control endplay.
- Axle tube:** Encloses the drive axles and extends to the rear wheels in a rear axle housing.

B

- Backlash:** A condition of clearance or movement between two closely mating mechanical parts. It is the amount of play between these parts.
- Ball bearing:** A bearing consisting of an inner and outer hardened steel race separated by a series of hardened steel balls. Classified as an antifriction bearing.
- Ball-and-cage joint:** A joint that consists of a set of ball bearings, an inner race, an outer race, and a ball cage.
- Ball-and-trunion U-joint:** In addition to allowing the drive shaft assembly to bend, this joint also allows fore-and-aft (forward and backward) movement of the propeller shaft. No used on modern vehicles.
- Bearing:** Used to reduce friction between rotating and stationary parts and guide and support rotating parts to prevent damage from misalignment or excessive clearances.

Bearing support bracket: Installed at the outboard end of the shaft. The bracket houses the intermediate shaft bearing and is attached to the transaxle assembly or to a stationary part of the vehicle chassis.

Bellhousing: Clutch housing that supports the transmission or transaxle and encloses the clutch.

Bevel gear: Gear used to connect shafts that run at angles. the bevel gear resembles a truncated cone.

Bleeder valve: Slave cylinder valve for bleeding air from the system.

Block synchronizer: Synchronizer consisting of an inner hub, outer sleeve, inserts, insert springs, and blocking rings.

Blocking ring: Toothed brass or copper ring that acts as a clutch to speed up or slow down the mating gears to match the speed of the output shaft.

Blown gasket: A gasket in which pressure has torn pieces from it.

Bolt: A threaded rod with a head on one end.

Bolt grade: The amount of pull, or tension, a fastener can withstand before it stretches or in some cases, breaks.

Bolt length: Length measured from the bottom of the bolt head to the end of the threaded section.

Bolt size: The major diameter of the bolt threads.

Boot: A pleated, or accordian-like, flexible cover made of synthetic rubber or plastic. It is used to retain lubricant and keep out contaminants while allowing part movement.

Boot protector: Protective covering for the outer CV joint boot.

Brake fluid: Hydraulic fluid that will not damage rubber components.

Brake micrometer: A specialized micrometer used to check brake drums and rotors for proper thickness and out-of-round conditions.

C

Cable linkage: A mechanical clutch linkage that transmits motion by means of an enclosed cable between the petal and the clutch fork.

Caliper: Tool used for external or internal measurements.

Cap screw: A bolt that threads into a part instead of a nut.

Cardan U-joint: See *Cross-and-roller U-joint*.

Case bearings: See *Side bearings*.

Central axle shaft: CV axle shaft used on a front-wheel drive vehicle.

Central differential: Compensates for changes in gear speed as the spider gears walk around the side gears.

Chain: Series of links.

Chain drive: A series of links, or a chain, and two or more gears called sprockets. The chain transmits motion between the tow sprockets.

Chain tensioner: Spring-loaded devices that maintain constant pressure on the return, or nondrive side of the chain.

Circular thickness: The thickness of a gear tooth measured between the faces and along the pitch circle.

Clearance: Space between the root of one gear tooth and the top of the mating tooth.

Cluster gear: See *Countershaft gear*.

Clutch: Connects or disconnects the flow of power from the engine to the drive wheels by means of a friction coupling. Used on vehicles with manual transmissions.

Clutch adjustment: Setting the correct amount of free play in the clutch linkage.

Clutch anticipation switch: Electrical switch that signals the vehicle computer when the clutch is depressed.

Clutch chatter: A specific type of vibration that is accompanied by a rapid clunking or rattling noise. It occurs while the clutch is being engaged.

Clutch cover: Part of the pressure plate assembly that is bolted to the flywheel and turns with the flywheel.

Clutch disc: Is splined to and transmits power flow to the transmission input shaft. It is held against the flywheel when the clutch is engaged.

Clutch drag: The clutch cannot be disengaged or it fails to release, and gears cannot be shifted. When the vehicle is stopped in gear (clutch pedal depressed), the engine stalls.

Clutch fork: Slides the throwout bearing into the pressure plate assembly.

Clutch housing: Encloses the entire clutch assembly to protect it from damage due to rocks, water, oil, and such.

Clutch linkage: Allows the driver to operate the clutch fork.

Clutch pedal: A lever with a rubber pad at one end. The other end of the pedal is attached to linkage that connects the pedal to the clutch fork.

Clutch-plate differential: Limited-slip differential that uses several friction discs that look like small manual clutch discs.

Clutch shaft: See *Manual transmission input shaft*.

Clutch slippage: The clutch disc does not grip firmly, and it slips between the flywheel and the pressure plate as the members rotate.

Clutch vibration: A vibration that can be felt inside the vehicle while the clutch is fully engaged. It varies with engine speed.

Coarse thread: Called UNC, which stands for Unified National Coarse.

Coil-spring pressure plate: Uses large coil springs, which are pressed between the pressure plate and the clutch cover.

Collapsible spacer: Maintains a mild pressure between the front and rear pinion bearings, making it possible to accurately adjust the pinion bearing preload.

Collar: Steel ring used to hold gears or bearings on a shaft.

Companion flange: See *Differential pinion flange*.

Cone differential: Limited-slip differential that uses a cone-shaped clutch to engage a matching cone-shaped receptacle.

D

Constant velocity: When axles transmit power through changing drive angles without variations in axle speed, or rpm.

Constant-duty throwout bearing: Throwout bearing which is always in contact with the release levers or fingers.

Constant-mesh transmission: A transmission in which all forward gears of the countershaft are in constant mesh with the mainshaft gears, which are free to rotate.

Constant-velocity axle: An axle that utilizes two constant velocity joints to effect power transfer to the driving wheels.

Constant-velocity U-joint: See *Constant-velocity universal joint*.

Constant-velocity universal joint: Flexible joint that provides a constant flow of power through angles between drive and driven shafts.

Control loop: A continuous series of inputs, EMC decisions and actions, and outputs.

Conventional mounting: Engine positioned so that the water pump and drive belts are in the front of the vehicle. The crankshaft centerline runs parallel to the centerline of the vehicle.

Conventional U-joint: See *Cross-and-roller U-joint*.

Core value: Return value of rebuildable parts.

Countershaft: The central shaft of the countershaft gear assembly.

Countershaft gear: A series of helical gears machined out of a single piece of steel. The largest gear on the countershaft gear is always the countershaft driven gear, which is the forward most gear. In addition to the driven gear, there is usually one gear on the gear cluster for each available reduction and overdrive ratio, plus a gear for reverse.

Countershaft gear assembly: A shaft and several gears, which rotate as a unit. Located between the input and output shaft gears, and acts as a third gear to restore the original direction of gear rotation.

Cross-and-roller U-joint: A center cross (or spider) and four cups (or caps) containing needle bearings. The cups are machined to fit the drive shaft yokes, the slip yoke, and the differential pinion yoke. The needle bearings allow the yokes to swivel in the cross ends with minimal friction.

Cushion spring: Flexible plate that compresses when the clutch is engaged, absorbing some of the shock of the engagement.

CV axle: See *Constant-velocity axle*.

CV axle shaft: Steel shafts that work with CV joints to transfer power between the transaxle and wheel hubs.

CV axle vibrations: Pulsations or other cyclical shocks caused by worn or damaged CV axle parts.

CV joint: See *Constant-velocity universal joint*.

CV joint boot: Used to protect CV joints by keeping the lubricant in and the contaminants out.

Damage: Condition short of failure, which if left uncorrected, will lead to a failure.

Department store service center: Many national chain and department stores have auto service centers where various types of automotive repairs are performed. They often hire technicians for entry-level jobs and may have several classifications above entry-level.

Depth micrometer: Measuring device used to measure the depth of openings in machined surfaces.

Diagnosis manual: Manual containing only the information needed to diagnose problems such as troubleshooting procedures and discussion of common problems.

Dial indicator: Gauge used on moving drive train parts to measure small amounts of movement.

Diaphragm-spring pressure plate assembly: type of apply spring that uses a single diaphragm spring.

Differential assembly: Gear system, which redirects the power flow and allows drive wheels to revolve at different speeds during vehicle turns.

Differential carrier: housing that serves as a container for rear axle assembly parts. The housing accommodates the suspension system attachment. Most rear axle housings are used to support the stationary parts of the rear brake assemblies. The housing also forms a reservoir for the rear end lubricant.

Differential case: One-piece unit with the ring gear bolted to the case and side bearings pressed onto the case.

Differential drive gears: Ring and drive pinion gears that redirect power flow by 90° and multiply engine power.

Differential pinion flange: Two-piece assembly, consisting of two mating flanged sections. One flange holds the rear universal joint, and the other connects to the pinion gear. The arrangement attaches the rear universal joint to the pinion.

Differential pinion yoke: Connects to the drive pinion gear in the rear assembly. the yoke has internal splines that fit external splines on the drive pinion gear shaft. The yoke is held to the shaft by a large locknut.

Direct drive: High gear; gear ratio of 1:1. There is no change in either speed or torque between engine output and transmission output.

Direct programming: The fastest and simplest method of reprogramming the ECM. the new information is downloaded by attaching a shop recalibration device (usually a computerized analyzer) or a programming computer directly to the vehicle's DLC.

DOT 3: Standard established by the Department of Transportation for modern brake fluids.

DOT 4: Standard established by the Department of Transportation for modern brake fluids.

Double Cardan U-joint: CV joint constructed with a cross-and-roller U-joint at each end of a special coupling yoke, called a center yoke. A central ball-and-socket connection acts as a centering device.

Double-helical gear: A variation of the herringbone gear. The opposing teeth have a space between them.

Downshifting: Moving the gearshift lever into lower gears.

Drain pan: Pan used to catch oil in that drips from assemblies as they are drained and disassembled.

Drift: Removal and installation tool designed to be struck with a hammer. Used to remove pins, plugs, and other pressed in parts from bores.

Driveline: See *Drive shaft assembly*.

Drive pinion gear: A hardened-steel gear with an integral shaft. It is machined to mesh with and rotate the ring gear.

Drive shaft: Means of transmitting power from the transmission to the rear assembly.

Drive shaft assembly: Assembly consisting of a drive shaft, front and rear universal joints, and front slip yoke. Provides a smooth delivery of power to the rear axle assembly, while allowing the rear axle to move up and down to compensate for road conditions.

Drive shaft assembly angles: The angles between the centerlines of transmission output shaft and the drive pinion gear shaft.

Drive shaft assembly vibration: Vibration caused by worn or damaged parts or shaft imbalance.

Drive train: The part of the vehicle that connects the engine to the drive wheels. It modifies engine power output to match vehicle needs.

Driver: Tool used to install and remove parts such as bearings and seals in housings and bushings.

Dummy shaft: A temporary shaft, such as a wooden dowel or a broomstick, used with a hammer to drive a shaft from its housing.

Dumping the clutch: Increasing engine speed and then suddenly releasing the clutch pedal, allowing the pressure plate apply springs to engage the clutch almost instantly.

Dust shield: Used in places where a seal would be exposed to large amounts of dirt and water.

Dynamic seal: Seal that flexes slightly to allow for the back-and-forth motion and slight rotation of the transmission or transaxle input shaft as the gears are changed.

Electronically controlled transfer case: The driver selects the transfer case range on this type of system by pressing dashboard-mounted switches or moving a floor-mounted lever.

End clearance: Distance between the end of a rotating shaft and a stationary housing or between two rotating shafts.

Endplay: Axial, or back-and-forth, shaft movement.

End thrust: The thrusting action that occurs along the shaft whenever power is transmitted through a helical gear.

Entrepreneur: A person with his or her own business. This type of person must be able to shoulder responsibilities, handle problems, and look for practical ways to increase business and make a profit. This type of person must maintain a clear idea of what plans, both long and short term, need to be made.

Environmental damage: Damage to the atmosphere caused by careless disposal of solid and liquid wastes and improper repair procedures.

Environmental Protection Agency (EPA): Agency that enforces laws that protect the environment.

Epoxy: Type of adhesive that is a two-part mixture applied in a one-step process.

Equal-length drive axle system: Drive axle system design in which an intermediate shaft allows the use of equal length CV shafts on each side of the vehicle.

Extension housing: Encloses the tail end of the transmission output shaft, which extends from the transmission case. It also encloses part of the shift linkage.

External floor-shift linkage: A linkage system in which the gearshift lever assembly mounts to the rear of the transmission, usually on the extension housing. The gearshift lever extends upward through a hole in the vehicle floor pan. The gearshift lever assembly transfers gearshift lever movement to the shift rods. The shift rods operate the shift levers on the transmission case.

External gasket: Gasket that keeps fluid from leaking out of a component.

External shift linkage: A linkage system, identified as a series of rods and levers, that connects to the outside of the transmission. Some later external systems use cables instead of rods.

Eyewash station: Safety device used to flush contaminants from the eyes.

E

ECM (Electronic Control Module): Single computer used to operate the engine, transmission, and transfer case.

EEPROM: Electronically erasable programmable read-only memory.

Electronic vibration tester: Tester, resembling a scan tool, that is used to locate the source of vibration. Instead of being placed directly on a suspected vibrating part, electronic vibration testers have a separate vibration sensor.

F

Faces: The contact surfaces of gear teeth.

Face shield: Provides protection when working with solvents or other harmful liquids.

Face width: The width of a gear tooth measured parallel to the gear axis.

Failure: The total breakdown in a system or component so that it can no longer fulfill its purpose.

Fastener: Device used to hold, or fasten, parts together.

Fault designator: Last two numbers in OBD II system five-character alphanumeric codes. The numbers identify the specific component (sensor, output device, or ECM) that might be causing a problem, as well as the type of fault detected.

Feeler gauge: Gauge used to measure spaces, or gaps, between two surfaces.

Fender cover: Protective cover placed over the fenders, upper grille, or other body sections to prevent vehicle damage.

FEPRM: Flash erasable programmable read-only memory. The computer memory section that can be updated.

Final drive: Final stage of a drive train. The rear axle assembly, which is a combination of the differential and drive axles, is sometimes referred to as the final drive.

Fine thread: Called UNF, which stands for Unified National Fine.

Flash programming: Providing existing computer memory with updated information.

Flywheel: Transfers engine power into the clutch, provides a mounting surface for parts of the clutch, and serves as an engine vibration damper and a clutch heat absorber.

Flywheel holder: Tool used to keep the flywheel from turning.

Flywheel turner: Tool used to move the flywheel by engaging two or more teeth on the flywheel ring gear.

Form-in-place gasket: Gasket made from a sealer.

Four-wheel drive system: Somewhat resembles a conventional rear-wheel drive system, but also has a front axle assembly and a separate gearbox called a transfer case.

Free play: The distance the clutch pedal will travel when first depressed before the slack in the linkage is taken up and any appreciable resistance is felt by the driver.

Free travel: See *Free play*.

Friction bearing: Bearing that is pressed into place and does not move. A rotating shaft slides around on the friction bearing's surface.

Friction disc: See *clutch disc*.

Friction facing: Makes up part of the clutch disc that contacts the flywheel and pressure plate.

Front bearing retainer: Holds the transmission front bearing in place and serves as a hub for the clutch throwout bearing and provides a sliding surface for the bearing assembly.

Front differential: A unit designed to transfer power from the front drive shaft assembly to the front wheels.

Front drive axle: Connected to the front differential assembly, and transfers power from the differential to the front wheels. The front drive axles are straight steel shafts when used with a solid differential assembly. When used with an independently sprung differential, the axles are equipped with cross-and-roller U-joints or CV joints for flexibility.

Front drive shaft assembly: Extends from the front of the transfer case to the front differential. It transfers power from the transfer case to the front differential.

Front-engine, front-wheel drive system: Engine is mounted longitudinally or transversely in the front of the vehicle. Power flows from the engine to the clutch, to the transaxle transmission, to the front drive axles, and to the front wheels. There is no drive shaft assembly in this system.

Front-engine, rear-wheel drive system: Engine is mounted in the front of the vehicle and connected by the drive shaft assembly to the rear axle assembly.

Full-floating axle: Solid drive axle in which the axle drives the wheel but does not carry any of the vehicle weight.

Full-time four-wheel drive system: Drives all four wheels at all times. Special drive train components are used in these systems to compensate for differences in speed and traction between the front and rear wheels. The driver has limited or no control over the operation of this system.

G

Gasket: A kind of static seal used on nonmoving parts.

Gauge: instrument used to measure something.

Gear: A toothed wheel.

Gear backlash: The amount by which the space between neighboring gear teeth exceeds circular thickness of a mating gear tooth. In general, the greater the amount, the more play there will be between two meshing gears.

Gear clash: A grinding noise that is heard when gears fail to mesh properly.

Gear disengagement: A condition in which transaxle transmission gears and synchronizers disengage on their own, causing the transaxle to come out of gear.

Gear drive: System of gears engaging other gears or mechanical parts for the purpose of transmitting power.

Gear jumpout: Condition in which transmission gears and synchronizers disengage on their own, causing a transmission to come out of gear. Components are fully engaged but something happens to force them out of engagement, into Neutral.

Gear oil: Heavy oil that provides lubrication for the gears and bearings in rear axle assemblies and in manual transmissions and transaxles.

Gear ratio: the speed relationship between two gears, determined by dividing the number of teeth on the driven gear by the number of teeth on the gear drive.

Gear reduction: the speed at the output shaft will be less than the speed of the input.

Gearshift lever: Hand-operated lever used in a manual transmission to select the proper gear.

Gear slipout: A condition in which transmission gears and synchronizers are never quite fully engaged when they should be. When this happens, gear rotation tends to push the synchronizer outer sleeve and mating gear out of engagement.

General repair shop: Takes in most types of work and offers a variety of jobs.

Government-operated repair shop: Many local, state, and federal government agencies maintain their own vehicles. Employees are generally paid on an hourly or weekly basis.

Grabbing clutch: The clutch engages with a jerk or shudder no matter how slowly and carefully it is applied.

Grade marking: Bolt head marking used to identify the tensile strength of a bolt.

Grease: Water-resistant lubricant that exists in a solid or semisolid state.

H

Halfshafts: Axle shafts used as independent front axles.

Hardening sealer: Sealer used on parts that remain assembled for long periods of time.

Hard shifting: A condition that occurs when the shift lever is difficult to move from gear to gear.

Harshness: a condition usually described as the action of a vehicle component that is harder or more severe than normal.

Head size: Size of hex head measured across the flats. This is the wrench size.

Helical gear: Gear used to connect parallel shafts. The teeth of helical gears are cut at an angle, called a helix angle, across the gear surface.

Helper: Performs basic service and maintenance procedures, such as installing and balancing tires, changing engine oil and filters, and installing batteries.

Herringbone gear: A variation of a helical gear in which the thrust forces of the two sides of the gear cancel each other.

Holding fixture: Holds large components such as transmissions, rear axle assemblies, and transaxles.

Hole gauge: Gauge used to measure small diameter holes or openings.

Hotchkiss drive: Drive shaft assembly that uses an open shaft with two or more U-joints.

Hub flange: Hub splines in the center of the clutch disc that engage the splines on the transmission input shaft.

Hydraulic linkage: Clutch linkage that uses the clutch pedal to develop hydraulic pressure. The hydraulic pressure transmits movement to the clutch fork.

Hydraulic locking differential: Locking differential consisting of a pump with internal and external gears, a ring-shaped pressure diaphragm, and a clutch pack that resembles the clutch pack used in a conventional locking differential.

Hydraulic locking transfer case: Uses a hydraulic pump, ring diaphragm, and clutch pack. The pump and clutch pack lock the front and rear axles together, causing the axles to turn at the same speed.

Hypoid gear: gear used in applications where power flow must be diverted by some angle. Similar to spiral bevel gears except that the shaft axial centerlines (rotational axes) do not intersect.

Hypoid gear lube: Gear oil with an additive that prevents oil from being squeezed out from between helical and hypoid gears as they revolve.

I

Idler gear: See *Reverse idler gear*.

In-car service: Clutch repairs made without removing major components.

Inclinometer: Tool that measures inclinations of the drive train parts, relative to a horizontal reference plane. The readings are used to calculate the difference between inclinations of two mating parts.

Independent auto repair shop: An automotive repair shop that is privately owned by an individual or a group of individuals.

Independent rear suspension: Incorporates jointed drive axles (no axle tubes) that allow for flexibility and independent axle movement.

Independently suspended drive axle: Used on vehicles with independent rear suspension. The axle consists of a central shaft with flexible joints—either conventional universal joints or CV joints—allow each wheel to move independently of the vehicle body and of each other.

Indirect programming: The proper scan tool is used to transfer information from a separate programming device to the ECM.

Inner hub: Splined to and rotates with the output shaft. It is held in a stationary position between the transmission gears. the hub also has external splines that mate with the outer sleeve.

Input sensors: Any sensor that provides information to a computer.

Inserts: Serve, in part, as detents. They fit into slots along the inner hub.

Insert spring: Fit around the backside of the inner hub, in the recessed area. They push against the inserts into engagement with the notches in the internal splines of the sleeve on its hub. This holds and centers the sleeve on its hub.

Inside micrometer: Measuring device used for measuring larger inside diameters or other part openings. The instrument is placed within the bore or other opening and adjusted to fit. It is read in the same manner as an outside micrometer.

Installer: Automotive service person who installs parts on vehicles.

Insulating: Procedure of using insulating material to absorb and eliminate NVH.

Integral carrier: This type of rear axle housing has a sheet metal inspection cover, sometimes called the differential cover, which can be removed to service the rear end components.

Interference fit: When one part is machined slightly larger than the space of the mating part into which it is fitted. the parts press together tightly and cannot be removed easily.

Intermediate shaft: A separate shaft mounted between the transaxle and the CV axle on the long side of the transaxle (side farthest from it's wheel assembly).

Internal gasket: Gasket that prevents crossover of fluids within a component.

Internal shift linkage: A linkage system found only on transmissions with floor-mounted gearshift levers. In many instances, the gearshift lever extends down into the extension housing. The transmission and floor pan openings are sealed with rubber boots.

Isolating: See *Insulating*.

J

Jam nut: Nut that holds the yoke/flange to the drive pinion gear shaft. The top threads of the nut are deformed to tightly grip the threads on the drive pinion gear shaft.

Jumper wire: Short piece of insulated wire with an alligator clip on each end, commonly used to bypass components and apply voltage to a component or section of a circuit.

K

Key: Used to prevent rotation between a machine part and a shaft.

Keyway: Slots cut into two mating parts for insertion of a key.

L

lateral runout: A measure of in-and-out movement, or the wobble. It is measured in the direction that is lengthwise to the centerline of the rotating object.

Left-hand thread: The fastener must be turned counterclockwise to tighten.

Limited-slip differential: Type of locking differential commonly found on modern trucks and SUVs.

Linkage: See *Clutch linkage*.

Lip seal: Seal used on rotating shafts in the drive train. The sealing element is designed to contact the rotating shaft. the contact is made in the form of a lip.

Live axle: See *Solid drive axle*.

Locking differential: Overcomes traction problems by sending some of the power to both wheels, while allowing the vehicle to make normal turns.

Locking hubs: Used to engage and disengage the front wheels from the front drive axles.

Longitudinal mounting: See *Conventional mounting*.

Lubricant: Materials, usually of a petroleum nature, that provide lubrication. they may also serve cooling, cleaning, sealing, and power transmission functions.

Lubricant leakage: An unwanted loss of lubricant.

lubricating oil: Lubricant that exists in a liquid state.

Lubrication: A treatment of some sort that coats drivetrain parts to reduce friction between them.

M

Machine blue: A deep blue dye mixed in a grease-like substance.

Machine screw: Smaller than cap screws and are flat across the bottom.

Main drive gear: Gear that is integral with the transmission input shaft.

Mainshaft: See *Manual transmission output shaft*.

Mainshaft gears: Include one gear for each available reduction ration and the overdrive ration, and typically a gear for reverse.

Major diameter: Larger diameter pertaining to screw threads. Applies to both internal and external heads.

Manual transaxle: Combination of a transmission and a differential assembly. The gears are operated by shift forks ismilar to those in a rear-wheel drive transmission. Different combinations of gears are selected to obtain the desired gear ratios.

Manual transaxle case: Encloses transaxle shafts, gears, synchronizers, shift forks and linkage, and lubricating oil. It also encloses the differential assembly.

Manual transaxle differential assembly: Receives power from the transaxle transmission. the differential assembly contains differential drive gears, spider gears, and side gears. It allows the vehicle to make turns, allowing each drive wheel to rotate at a different speed.

Manual transaxle input shaft: Receives power from the engine through the clutch.

Manual transaxle output shaft: Contains gears that mate with the input shaft. This rotating shaft, which holds output gears and synchronizers, delivers power to the transaxle differential.

Manual transaxle shaft: A shaft that supports gears and directly or indirectly transfers rotation from the clutch disc to the transaxle differential assembly.

Manual transaxle shift linkage: Connects the gearshift lever to the shift forks. Linkage consists of shift levers and rods or cables.

Manual transmission: System with several gear ratios to allow for efficient operation under various conditions. The vehicle operator makes the gear selection decisions. Transmission gears and gear synchronizers are moved in and out of engagement by shift forks.

Manual transmission case: Encloses transmission shafts, gears, synchronizers, shift forks, linkage, and lubricating oil. In some designs, it is combined with the clutch housing.

Manual transmission input shaft: A rotating shaft that transfers rotation from the clutch disc to the countershaft gear. It delivers power to the transmission.

Manual transmission output shaft: A rotating shaft that delivers power to the drive shaft assembly and holds the output gears and synchronizers.

Manual transmisssion shaft: Supports gears and directly or indirectly transfers rotation from the clutch disc to the drive shaft assembly.

Manual transmission shift linkage: Allows the driver to operate the shift forks.

Master cylinder: Controlling cylinder in hydraulic linkage. It develops the system hydraulic pressure.

Master Technician: If a technician passes all the tests in the automotive or heavy truck areas, he or she is certified as a Master Technician in that area.

Mechanical shift system: Part-time four-wheel drive system shift mechanism that allows the driver to select various gears and driving modes. A shift lever operates the shift rails of the transfer case. Forks operate the sliding clutch sleeves that select various gear ratios.

Metal ladder clamps: Clamps used on CV joint boots. Similar to cooling system hose clamps.

Metal spring clamp: Clamp that holds CV joint boots in place.

Metric thread: Called SI, which stands for International System of Units (English translation).

Micrometer: Gauge with a graduated scale from which very accurate measurements are read.

Mid-engine, rear-wheel drive system: Engine is mounted longitudinally and a transaxle drives the rear wheels. Power flows from the engine (through the clutch in the manual transaxles) into the transaxle transmission. From here, power flows directly into the differential section of the transaxle and then to the drive wheels.

Minor diameter: Smaller diameter pertaining to screw threads. Applies to both internal and external threads.

Multimeter: Combination meter capable of measuring ohms, volts, and amps.

Multiple plate clutch pack: A series of clutch plates. Clutch packs can be used to transmit power or to lock parts of the gear train to the case.

N

National Institute for Automotive Excellence (ASE): A nonprofit organization formed to encourage and promote high standards of automotive service and repair. ASE does this by providing a series of written tests on various subjects in the automotive repair, truck repair, auto body, and engine machinist areas.

Needle bearing: Type of roller bearing with tiny rollers that resemble needles.

Neutral safety switch: Electrical switch that is always attached to the pedal linkage in a clutch pedal assembly.

New dealership: New vehicle dealerships have large, well-equipped service departments to meet the warranty service requirements of the vehicle manufacturer. These service departments are usually equipped with special testers, tools, and service literature needed to service the make of vehicle they sell. Dealership service departments are also equipped with lifts, parts cleaners, hydraulic presses, brake lathes, electronic test equipment, and other equipment for efficiently servicing vehicles.

No-drive condition: When the transmission will not transmit power from the engine to the drive wheels.

Nonhardening sealer: Sealer used on parts that will be taken apart occasionally.

Nonpositive seals: Seals that provide controlled leakage of fluid to allow some lubrication of moving parts.

Nonthreaded fastener: A device, such as a snap ring, used to hold, or fasten, parts together without the use of threads.

Nut: A threaded fastener with inside threads and, commonly, a six sided outer shape.

Nut size: The minor diameter of the nut threads.

NVH: Abbreviation for noise, vibration, and harshness.

O

Oil clearance: Clearance between the shaft and bearing to allow the lubricant to enter and circulate properly.

Operating angles: See *Drive shaft assembly angles*.

O-ring: A round ring seal. Most O-rings have a small diameter through the cross-section as compared to the annulus, or ring.

Outer disc assembly: The portion of the clutch disc consisting of a plate of thin steel sandwiched between friction material called the clutch disc friction facing.

Outer sleeve: Has internal splines that mate with the external splines of the hub. The internal splines of the outer sleeve also mate with the straight-cut teeth of the gears next to which they are mounted.

Output devices: Any device that performs an action as requested by the ECM. In a transfer case, small motors that select the proper range by moving the internal transfer case linkage are a type of output device.

Outside micrometer: Measuring device consisting of a frame, sleeve, thimble, spindle, and anvil. The opening between the anvil and spindle is made larger or smaller by turning the thimble. The size of the opening is read on the sleeve and thimble.

Overdrive: Gear ratio of around 1:1.5, allowing the engine to run more slowly than a higher gear ration would permit at the same speed of travel.

Overhaul manual: Manual containing comprehensive information needed to disassemble, inspect, and reassemble vehicle components.

P

Parts specialist: Keeps the supply of parts flowing through the system until they reach the ultimate endpoint, the vehicle.

Parts washer: A tank used to clean automotive parts. Depending on the type of parts washer, it may be filled with a cleaning solvent or a strong corrosive chemical. Some part washers have a pump to circulate the cleaning solution. Two common part washers are the cold-soak tank and the hot tank.

Part-time four-wheel drive system: In the original four-wheel drive system, the vehicle operator directly controls the drive train parts that send power to two or four wheels. On some newer vehicles, an on-board computer makes the decisions, and the driver only partially controls the system.

Pattern failure: A problem that is common to a certain type of vehicle.

Pawl-and-quadrant assembly: An assembly used on a self-adjusting cable to automatically correct inconsistencies in the linkage due to wear.

PCM (Powertrain Control Module): Single computer used to operate the engine, transmission, and transfer case.

Pedal reserve: The amount a clutch pedal can still be depressed beyond the point where the clutch is fully disengaged.

Peening: Indentations in the gear faces, usually caused by severe loads on the gear teeth or by large particles of foreign matter in the lubricant.

Perfect alignment: When all centerlines line up exactly, forming one long centerline.

Pick: Pointed tool useful for prying parts.

Pilot bearing: Bearing that fits into the bore at the center of the crankshaft flange, providing the front support for the transmission input shaft.

Pile bushing: Bronze bushing that fits into the bore at the center of the crankshaft flange, providing the front support for the transmission input shaft.

Pinion bearings: Two tapered roller bearings that support the drive pinion gear.

Pinion gears: See *Spider gears*.

Pinion pilot bearing: Extra support bearing at the end of the pinion gear in some removable carriers.

Pinion shim: Installed in the housing, behind the rear bearing cup. The thickness of this shim determines the depth of the pinion gear in the housing.

Pitch circle: An imaginary circle around the gear located about midway between the outside diameter and the root diameter.

Pitting: Small holes, or pits, in the gear teeth, usually caused by abrasive particles or corrosion.

Pivot rings: Two rings built into the pressure plate assembly, located near the outer rim.

Plain bearing: See *Friction bearing*.

Planet carrier: The part in a planetary gearset to which the planet gears are attached. It is located in the center of the ring gear.

Planet gears: Gears surrounding and meshed with the sun gear.

Planet pinions: See *planet gears*.

Planetary gearset: Gear assembly used in transfer cases, manual transmissions with overdrive units, and automatic transmissions. They provide gear reduction, direct drive, and overdrive.

Planet-pinion carrier: See *Planet carrier*.

Plunging joint: A joint that is designed to change its length.

Popping the clutch: See *Dumping the clutch*.

Power flow: Path for engine power consisting of various mechanical and, sometimes, hydraulic and electronic components of a drive train.

Preload: Mild pressure on an installed bearing.

Press: Piece of equipment consisting essentially of a frame and a ram. Used for applying pressure on an assembly.

Press fit: Type of interference fit in which considerable pressure is applied to the mating pieces to fit them together.

Pressure plate: Locks the friction disc between itself and the flywheel. The entire assembly is driven at flywheel speed.

Pressure plate assembly: Puts spring pressure on its pressure plate to tightly hold the clutch disc against the flywheel, keeping the clutch engaged.

Primary seal: Piston seal used by master and slave cylinders on the fluid end of the piston. The seal keeps the fluid from leaking out so the system can be pressurized.

Programming device: May resemble a personal computer used in the home, or it may be a computerized analyzer that is similar to the one used for direct programming.

Propeller shaft: See *Drive shaft*.

Prussian blue: See *Machine blue*.

Puller: Device that removes parts that are pressed together by exerting pressure on such parts to separate them.

Punch: Removal and installation tool designed to be struck with a hammer. Used to remove pins, plugs, and other pressed-in parts from bores.

R

Race: Housing made up of one or two pieces of metal that contain the rolling elements of an antifriction bearing.

Rack-and-pinion gear: Gear used in steering systems. The rack is a flat bar with teeth cut into it. The pinion is a small gear.

Radial load: Perpendicular to the axis of rotation.

Radial runout: A measure of out-of-roundness. It is measured at right angles to the centerline of an object.

Radial vibration: A side-to-side movement of a rotating part along its rotational axis.

Range and gear ratio control transfer case: Type of automatic four-wheel drive that automatically selects high or low gear ratios in two- and four-wheel drive ranges. This system is used on larger sport utility vehicles.

Range control only transfer case: Type of automatic four-wheel drive used on light-duty vehicles to select between two- and four-wheel drive but has a single gear ratio.

Ratchet differential: Uses a series of cams and ramps to direct power to the wheel with the most traction.

Rear axle assembly: Assembly consisting of a differential assembly and drive axles. Sends power from the driveline to the drive wheels.

Rear axle housing: Housing containing the differential assembly, drive axles, and related parts, forming a rigid support for the rear of the vehicle.

Rear axle ratio: The number of teeth in the ring gear compared to the number of teeth in the drive pinion gear.

Rear bearing: Provides the central support for the output shaft.

Rear differential: Identical to that of a rear axle assembly used on a two-wheel drive vehicle. It contains the ring and drive pinion gears and the differential case gears.

Rear drive axle: Connected to the rear differential. The axles may be straight shafts, or they may be equipped with cross-and-roller U-joints or CV joints. Transmits power from the differential assembly to the rear wheels.

Rear drive shaft assembly: Extends from the transfer case to the rear axle assembly. It is identical in design and operation to the drive shaft assembly used in two-wheel drive vehicles. Most drive shaft assemblies have at least two universal joints to provide flexibility. They also have a slip yoke to allow for changes in shaft length.

Rear end: See *Rear end assembly*.

Rear-engine, rear-wheel drive system: Engine, transaxle, and rear drive axles are all mounted in the rear of the vehicle.

Recertification test: Tests that a technician must take every five years to maintain a given certification.

Reed tachometer: A mechanical device with rows of small reeds arranged so that each reed vibrates at a slightly higher frequency than the reed to the left. This allows the technician to observe vibrations as their frequency changes.

Refrigerant: A liquid used in refrigeration systems to remove heat from the evaporator and carry it to the condenser. Automotive systems use R-12 and R-134A.

Relearn mode: A period of vehicle operation that allows the computer system to adapt to new components and updated programming.

Release bearing: Applies force to the release levers or fingers to disengage the clutch.

Release finger: See *Release lever*.

Release fork: Transfers the force of the clutch pedal and linkage to the throwout bearing.

Release lever: A device used on a coil-springed pressure plate to overcome the spring pressure and pull the pressure plate away from the friction disc. The release lever is hinged to the clutch cover and pivots on the hinge when engaged.

Remote programming: Programming done with the ECM removed from the vehicle.

Removable carrier: Separate housing for the differential assembly that can be unbolted and removed from the rest of the rear axle housing after the drive axles are removed.

Retainer plate: Used to hold gears and bearings in position.

Return springs: Springs that return the clutch fork and linkage to their normal, or released, positions.

Reverse gear: Gearshift position that allows a vehicle to move in the reverse direction (back up).

Reverse idler gear: Turns the output shaft in the same direction as the countershaft gear assembly, which is opposite to the direction of the input shaft. Does not change the gear ratio.

Reverse idler shaft: A short shaft that supports the reverse idler gear.

Reverse lockout solenoid: Solenoid that prevents reverse engagement when the vehicle is moving forward.

Riding the clutch: Driving with a foot resting on the clutch pedal.

Right-hand thread: The fastener must be turned clockwise to tighten.

Ring and pinion: Pinion gear and ring gear. These gears redirect the powerflow 90° to drive the rear wheels.

Ring and pinion gearset: Ring and pinion gears that redirect powerflow by 90° and multiply engine power.

Ring gear: Gear meshed with the planet gears. Transfers power from the drive pinion gear to the differential case.

Ring gear backlash: The clearance, or play, between the ring and pinion gears.

Ring gear contact pattern: Pattern of wear on the gear teeth of the drive side and the coast side.

Ring gear runout: The amount of wobble when the ring gear is rotated.

Ring seal: A flexible ring that fits between two parts to keep fluid from leaking between them. Ring seals are used to seal stationary parts or circular parts that slide in their bores.

Rod-and-lever linkage: A mechanical clutch linkage that depends on a set of rods and levers to transmit movement from pedal to clutch fork.

Roller bearing: A bearing that contains hardened roller ball bearings between two races. Classified as an antifriction bearing.

Roller chain: Chain with rollers that rotate on drive pins. The rollers contact, which reduces friction between the chain and sprocket.

Root: The base of the gear tooth.

Rotational axis: See *Axial centerline*.

RTV (room temperature vulcanizing) sealer: A silicone sealer that cures to a rubber-like consistency to form a gasket.

Rubber ring: Holds CV joint boots in place.

Running fit: Sufficient oil clearance to enable parts to turn freely and receive proper lubrication.

Runout: A condition of a rotating object, such as a shaft or flywheel, in which the surface is not rotating in a true circle or plane.

Rzeppa joint: Flexible joint used in front drive axles.

S

SAE viscosity rating: Classifies the lubricant by its viscosity.

Safety areas: Areas in the shop where extra alertness and safety precautions are needed.

Safety glasses: Protects the eyes from flying metal and dirt.

Salesperson: The salesperson performs a vital service, since repairs will not be performed unless the owner of the vehicle is sold on the necessity of having them done.

Salsbury drive: Drive shaft assembly in which the coil springs are used to attach the rear axle to the vehicle.

- Scan tool:** Tool used to access the computer's self-diagnostic system. The scan tool retrieves trouble codes stored in the body of the computer and performs other diagnostic tasks.
- Schematic:** A graphic representation of a hydraulic, pneumatic, or electrical system.
- Scoring:** Scratches on gear teeth faces caused by improper machining or lack of lubrication.
- Screw:** Threaded fastener designed to thread directly into a nut or threaded hole.
- Screw extractor:** Tool used to remove broken screws or other fasteners from parts.
- Seal:** Device that keeps fluids, such as lubricant, within a compartment or desired space. It also keeps contaminants such as air, dirt, and water from getting in such places.
- Sealant:** See *Sealer*.
- Sealer:** Used to improve the sealing ability of a gasket, take the place of a gasket, hold a gasket in place during reassembly, or improve the sealing ability of dynamic seals and hose connections.
- Seal protector:** Metal or plastic sleeves used to prevent seal damage when a seal is installed over a shaft that has a sharp area such as a keyway.
- Seat cover:** Protective cover placed over the seats to protect them from dirt, oil, and grease that might be on your work clothes.
- Seal ring:** Metal or Teflon™ rings that seal oil pressure directed to or through passageways in rotating shafts or drums.
- Secondary seal:** Piston seal that is used by master and slave cylinders on the pushrod end of the piston to keep system fluid from leaking out of the cylinder.
- Self-adjusting cable:** Provision in cable linkage for self adjustment to compensate for wear, usually occurring in the cable or clutch disc.
- Semi-centrifugal clutch:** Clutch with release levers that have additional weight added to their outer ends. The weights are situated such that when the pressure plate assembly is rotating, they tend to be thrown out to a larger diameter. The resulting action causes the weights to exert additional pressure against the pressure plate. This helps the springs to hold the friction disc tightly at high engine speeds. As a result, lighter springs can be used making it possible to operate the clutch with less effort.
- Semi-floating axle:** Solid drive axle in which the weight of the vehicle passes through the axle bearing to the drive axle and on to the wheel and tire.
- Service advisor:** See *Salesperson*.
- Service literature:** Provides the specifications and the step-by-step instructions to properly service a particular vehicle.
- Service manager:** See *Shop foreman*.
- Seven-step troubleshooting process:** Enables the technician to quickly isolate vehicle problems. This process uses seven logical steps to reach a conclusion about what is wrong. The seven-step process also works to troubleshoot any NVH problem.
- Shellac:** A gummy, sticky substance that remains pliable.
- Shift collar:** See *Sliding clutch sleeve*.
- Shift fork:** prolonged unit for moving transmission gears or synchronizers on their shaft for gear engagement.
- Shim:** A thin sheet of metal that is placed between two surfaces to keep them apart.
- Shop foreman:** A managerial position in an automotive repair shop.
- Side bearing preload:** The amount of force pushing the side bearings of the differential case together.
- Side bearings:** Bearings installed on the outer ends of a solid rear axle assembly. Sometimes used to refer to the differential carrier bearings.
- Side gears:** In a standard differential, the side gears are splined to the drive axles. They transfer power to the drive axles and rear wheels.
- Silent chain:** A series of flat metal links, which provide quiet operation. The links have teeth that engage matching teeth in the sprockets.
- Single-pull differential:** See *Standard differential*.
- Size gauge:** Linear measurement devices used for measuring part dimensions and clearances (the space between two parts).
- Skid plate:** Protective undercarriage panel of a transfer case.
- Slave cylinder:** Operating cylinder in hydraulic linkage. It is actuated by the hydraulic pressure developed in the master cylinder.
- Sliding clutch sleeve:** The planetary gears used in the transfer cases are mechanically selected by moving the sliding clutch sleeve, or shift collar as it is sometimes called, in and out of engagement.
- Slip yoke:** Connects through the U-joint to the front of the drive shaft. It slides back and forth within the transmission, allowing the drive shaft length to change with rear axle movement. It may also be mounted at the rear of the front drive shaft in four-wheel drive vehicles.
- Snap ring:** A split ring used for holding parts on shafts or inside bores.
- Snap ring pliers:** Special service tool used for removing and installing snap rings or retainer rings.
- Solid-axle rear suspension:** Incorporates rigid and nonflexible drive axles and axle tubes. Both wheels move as one solid unit in response to bumps and potholes.
- Solid drive axle:** A hardened-steel shaft. External splines on the inboard (inner) end of each axle mate with internal splines on the differential side gear to which it is connected.
- Spalling:** A condition in which sections of the gear teeth flake or chip off, which can be caused by a lack of lubrication or severe gear loads.
- Spanner wrench:** A special service tool used to tighten large parts or to hold parts in place while other tools are used.
- Special service tools:** Tools exclusively designed to service a specific component or a specific class of components.
- Specialty shop:** Confines its repair work to one area of repair, such as transmissions, tune-up, brake repair, or alignments.
- Spider gears:** gears made of hardened steel and held in place by a steel shaft called the pinion shaft.

Spindle: Outer stub shaft.

Spiral bevel gear: A variation of the bevel gear in which the gear teeth are curved.

Spline: A type of slot that is cut into a shaft or other part. The slot runs longitudinally, or lengthwise, to the axis of rotation. Splines allow two parts to move back and forth in relation to each other, while allowing power to be transferred through them.

Splined shaft: Shaft that has many equally spaced splines. Splines may be internal or external. The internal splines of one shaft are designed to mate with the external splines of another shaft.

Split-case transmission: Two piece type transmission case. The gears and shafts can be lifted out of a case once the case halves are split.

Sprocket: Gear in a chain drive.

Spur gear: Gear used to connect parallel shafts. The teeth on spur gears are always cut straight across, or axially.

Standard differential: Meshing spider and side gears enclosed in a differential case.

Standard transmission: See *Manual transmission*.

Standardized tests: The same test in a particular subject is given to everyone who takes it.

Static seal: Stationary ring seal that fits between nonmoving parts and forms a perfect seal with no fluid leakage.

Steering wheel cover: Protective cover placed over the steering wheel to protect it from dirt, oil, and grease that might be on your hands.

Straightedge: Measuring tool used to check for warping of part surfaces.

Straight roller bearing: Bearing that usually comes as a one-piece unit and is used for axle bearings in rear axle assemblies. Also used in manual and automatic transmissions.

Strap-and-buckle clamp: Clamp that holds CV joint boots in place.

Stub shafts: Connected to the center shaft through the CV joints. In many systems, one or both stub shafts are part of the outer CV joint housing.

Sun gear: Gear in the center of a planetary gearset.

Synchromesh transmission: Transmissions that are synchronized in forward gears.

Synchronizer: Brings certain transmission gears to the same rotational speed as the output shaft before sliding in mesh with them to lock them to the output shaft.

T

Tapered roller bearing: Bearing used in rear axles and front-drive axles. Rollers of this bearing assembly are tapered.

TCCM (Transfer Case Control Module): Separate computer used to operate the transfer case.

Telephone hotline: Technical support service provided by a manufacturer or parts supplier.

Telescoping gauge: Gauge generally used to measure larger holes or openings.

Tensile strength: The amount of tensile force a fastener can withstand before it stretches, or in some cases, breaks.

Test lights: Devices used to check whether electricity is reaching a particular point in the electrical circuit or to detect a circuit that is not allowing current to flow.

Test score report: A confidential report of your performance on ASE tests. The report lists the number of questions that must be answered correctly to pass the test, and the number of questions you answered correctly.

Thread fastener: Any fastening device that uses threads to tighten and hold, such as bolts, nuts, and screws.

Thread length: Measure of external thread length.

Thread-locking compound: Type of anaerobic sealer to prevent threaded fasteners, such as bolts, screws, and nuts, from loosening.

Thread pitch: Distance measured across crests of adjacent threads.

Thread-pitch gauge: A tool to measure the distance across the crests of adjacent threads.

Thread sealer: Used to seal any threaded fasteners that extend into the oil-lubricated interior of a drive train component.

Throwout bearing: Bearing that is pushed along the input shaft into the pressure plate assembly when the clutch pedal is depressed. This causes the force from the pressure plate to be removed from the clutch disc, disengaging the clutch.

Thrust bearing: Flat, disc-shaped bearing that resembles a washer. The needle rollers are arranged radially.

Thrust load: See *Axial load*.

Thrust washer: Washer used between the end of a rotating shaft and a stationary housing or between two rotating shafts. Prevents excessive axial, or back-and-forth, shaft movement by limiting the amount of end clearance.

Tightening sequence: Pattern for tightening threaded fasteners that ensures parts are fastened evenly.

Torque converter: Connects or disconnects the flow of power from the engine to the drive wheels by means of a fluid coupling. Used on vehicles with automatic transmissions.

Torque specification: Threaded fastener tightening values.

Torque steer: Undesired turning effect due to the difference in drive angles in an unequal-length drive axle system causing one wheel to receive more torque during acceleration.

Torque-tube drive: Drive shaft assembly with a drive shaft that is solid steel and enclosed in a tube. The tube is solidly connected to the rear axle assembly with bolts.

Torque wrench: A combination wrench and measuring device. It is used to apply a measured turning force, or torque to a threaded fastener.

Torrington bearing: See *Thrust bearing*.

Torsen differential: A locking differential using complex gearsets.

Torsion spring: Coil springs in a clutch disc that keep the rivets positioned to one end of the disc slots, toward the direction of rotation.

Transaxle: Combination of a transmission and a differential assembly.

Transaxle transmission gears: Gears that transmit power and provide a means of changing vehicle torque, speed, and direction.

Transfer case: Mechanical unit that splits power between the front and rear wheels (axles). It is attached to the rear of the transmission or transaxle and receives power from the transmission or transaxle output shaft.

Transfer case housing: Holds and aligns the transfer case shafts, gears, chains, and bearings. Also serves as a reservoir for the lubricating oil.

Transfer case input shaft: See *Transfer case mainshaft*.

Transfer case mainshaft: Receives power from the transmission or transaxle and transfers it to the other transfer case components.

Transfer case oil pump: Used to provide lubricating oil to various transfer case components.

Transfer case shudder: A jerking motion that typically occurs during acceleration. Possible shudder causes are low fluid level, loose transfer case fasteners, worn gears or bearings, or defective internal clutches.

Transmission: Multiplies engine torque or reduces engine rpm to match varying forward operating conditions and provides a way to move a vehicle in the reverse direction.

Transmission front bearing: Antifriction bearing that provides the rear support for the input shaft.

Transmission gear: Transmits power and provides a means of changing torque, speed, and direction at the gearbox output.

Transmission input shaft: Long shaft that extends from the rear of the engine crankshaft to the inside of the transmission case. It supports the clutch disc, holds it in proper alignment with the other clutch components, and transmits rotation from the clutch disc into the transmission.

Transmission jack: Jack used to remove and install transmissions.

Transverse mounting: Engine is installed at a 90° angle to the vehicle's centerline.

Tripod joint: Joint used as the inboard, plunging CV joint on many CV axle assemblies. This type of joint contains a three-point cross, or spider, assembly, which is attached to the axle shaft through a splined connection.

Tri-pot joint: See *Tripod joint*.

Troubleshooting chart: Chart containing the logical steps used to proceed to the cause of a problem.

Two-piece drive shaft: A drive shaft that is divided into two sections, with a universal joint between the front and rear sections.

U

U-joint: See *Universal joint*.

U-joint angles: See *Drive shaft assembly angles*.

Unequal-length drive axle system: CV axle system in which the drive axles used on each side of the transaxle are unequal in length.

Universal joint: Joint that allows for changes in the driveline angles when the rear axle is moving up or down over road surface irregularities.

Upshifting: Moving the gearshift lever to the next higher gear.

V

Vacumm shift system: Disconnects the front axle from the drive shaft when the vehicle is in the two-wheel drive mode.

Vibration order: The number of times a vibration occurs during one revolution of the rotating part.

Viscosity: Thickness, or resistance to flow.

Viscous coupling: A series of alternately splined plates that often have small ridges or other indentations.

W

Waveform meter: Meter capable of reading and displaying waveforms produced by electrical and electronic devices. A waveform meter can be a separate unit or built into a multimeter.

Wear: Erosion of a surface caused by relative motion between two parts.

Wear sleeve: Provides a riding surface for the sealing lip. The wear sleeve is pressed on the CV joint housing, and the seal is pressed into the steering knuckle.

Welding: Condition in which mating gear teeth overheat, melt together, and then pull apart as the gear turns.

Wheel balancer: Device used to spin wheel and tire assemblies and brake drums to check for imbalance.

Wheel bearing: Supports the CV axle stub shaft, allowing the shaft to transfer power through the front steering knuckle or through the rear steering support.

Wheel hop: Condition in which a tire skips over the road surface.

Wheel hub and bearing assembly: Supports the outer hub shaft. The shaft passes through the knuckle and rotates on the wheel bearings. The bearings support the wheel hub and maintain alignment between the hub and the knuckles.

Whole depth: Distance from the outside diameter of the gear to the root diameter.

Work order: A form used by technicians to record information about a vehicle being serviced. Also called a *repair order*.

Working depth: The overlap measured between outside diameters of two gears.

Worm gear: Gear that connects shafts that run at a 90° angle. It is used when a large speed reduction is needed.

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